Comment and Response Document

Proposed Amendments to the Administrative Manual and Special Regulations Regarding High Volume Hydraulic Fracturing Activities; Additional Clarifying Amendments

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Acronym	Definition
ABB	Appalachian basin brines
Act 13	2012 Amendments to Pa Oil and Gas Development, 25 Pa. Code Ch. 78a
AER	Alberta Energy Regulator
ALL	ALL Consulting
AMC	Appalachian Mountain Club
ANSI	American National Standards Institute
APE	Anticipated Productive Extent
API	American Petroleum Institute
ASTDR	U.S. Agency for Toxic Substances and Disease Registry
Bcf	Billion cubic feet
BMP	Best Management Practice
BOD	Biological oxygen demand
BOD5	Five-day biological oxygen demand
BOGM	Bureau of Oil and Gas Management
BTEX	Benzene, ethylbenzene, toluene and xylene
CAS	Chemical Abstracts Service
CBI	Confidential business information
CCST	California Council on Science and Technology
C.F.R.	Code of Federal Regulations
CH_4	Methane
CO_2	Carbon Dioxide
COA	Consent Order and Agreement
COD	Chemical oxygen demand
COGCC	Colorado Oil and Gas Conservation Commission
CPDB	Carcinogenic Potency Database
CRP	Center for Rural Pennsylvania
CRSD	Center for Responsible Shale Development
CSL	Clean Streams Law
CWA	Clean Water Act
CWIA	Center for Work Information and Analysis, PA Dept. of Labor
CWT	Centralized waste treatment
CWTP	Centralized waste treatment plant
DBNPA	2,2-dibromo-2-nitrilopropionamide, an electrophilic biocide commonly used in hydraulic fracturing.
DBP	Disinfection byproduct
DCS	Damascus Citizens for Sustainability
DNA	Deoxyribonucleic acid
DRB	Delaware River Basin
DRBC	Delaware River Basin Commission

Acronym	Definition
DRN	Delaware Riverkeeper Network
dSGEIS	Draft Supplement Generic Environmental Impact Statement (2009)
E&S	Erosion and sediment control
EDC	Endocrine disrupting chemical
EF	Eagle Ford shale oil and gas play of Texas
EIA	U.S. Energy Information Administration
ELGs	Effluent limitations guidelines and standards
EPA	Environmental Protection Agency
EPT	The EPT index is the number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
ER	Estrogen receptor
ERCB	Energy Resources Conservation Board
ES&T	The journal Environmental Science and Technology
EV	Exceptional Value
FracFocus	FracFocus Chemical Disclosure Registry
FSGEIS	Final Supplemental Generic Environmental Impact Statement
FV	Fayetteville shale gas play of Arkansas
GAO	Government Accountability Office
GHG	Greenhouse gas
GLD	Gas leak drainage
GOR	Gas to oil ratio
GWP	Global warming potential
GWPC	Ground Water Protection Council
H&S	Health and Safety
HESI	Halliburton Energy Services, Inc.
HF	Hydraulic fracturing
HQ	High Quality
HV	Haynesville shale gas play of Louisiana and Texas
HVHF	High volume hydraulic fracturing
IARC	International Agency for Research on Cancer
IOGCC	Interstate Oil and Gas Compact Commission
IPCC	Intergovernmental Panel on Climate Change
LC	Lethal concentration
LC50	A statistically derived concentration of a substance in an environmental medium expected to kill 50 percent of organisms in a given population under a defined set of conditions.

Acronym	Definition
LD50	A statistically derived dose of a chemical or physical agent (radiation) expected to kill 50 percent of organisms in a given population under a defined set of conditions.
M	Moment magnitude, a measure of earthquake magnitude
Mcf	Million cubic feet
MGD	Million gallons per day
MGM	Million gallons per month
MSC	Marcellus Shale Coalition
MTBE	Methyl tertiary butyl ether
NETL	National Energy Technology Laboratory
NJCP	New Jersey Coastal Plain
NMI	Northeast-Midwest Institute
NORM	Naturally occurring radioactive materials
NOV	Notice of violation
NPDES	National Pollutant Discharge Elimination System
NYC	New York City
NYSDOH	New York State Department of Health
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
O&G	Oil and gas extraction
ODNR	Ohio Department of Natural Resources
OGW	Oil and gas wastewater
PA	Pennsylvania
PADCNR	Pennsylvania Department of Conservation and Natural Resources
PADEP	Pennsylvania Department of Environmental Protection
PCBs	Polychlorinated biphenyls
pCi/g	PicoCuries per gram, a unit of measurement for radioactivity in a unit mass of sediment
pCi/L	PicoCuries per liter, a unit of measurement for radioactivity in a unit volume of air or water
PIOGA	Pennsylvania Independent Oil and Gas Association
POTW	Publicly owned treatment works
PSE	Physicians, Scientists and Engineers for Healthy Energy
PubMed	Searchable Database of the US National Library of Medicine, National Institutes of Health
PWSA	Pittsburgh Water and Sewerage Authority
Ra-226	Radium 226
Ra-228	Radium 228

Acronym	Definition
rdSGEIS	Revised Draft Supplement Generic Environmental Impact Statement (2011)
RPP	Rules of Practice and Procedure
RV	Recreational vehicle
RWQMN	Remote Water Quality Monitoring Network of the Susquehanna River Basin Commission
SCP	Sustained casing pressure
SGEIS	Supplemental Generic Environmental Impact Statement
SMCL	Secondary Maximum Contaminant Level
SPW	Special Protection Waters
SRBC	Susquehanna River Basin Commission
STRONGER	State Review of Oil and Natural Gas Environmental Regulations
TAMEST	The Academy of Medicine, Engineering and Science of Texas
TDS	Total dissolved solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
THM	Trihalomethane
THM4	The sum of mass concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
TOC	Total organic content
TPH	Total petroleum hydrocarbons
TRPH	Total recoverable petroleum hydrocarbons
TS	Trade Secret
TSS	Total suspended solids
TTHM	Total Trihalomethanes
TTPC	Tributyl tetradecyl phosphonium chloride
U.S.C.	United States Code
UCM	Unresolved complex mixture
UDS&RR	Upper Delaware Scenic and Recreational River
UIC	Underground injection control
UOG	Unconventional oil and gas
US or U.S.	United States (of America)
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VOC	Volatile organic compound
WC	Delaware River Basin Water Code
WQI	Water Quality Index
WSDL	Water Supply Determination Letters

EXECUTIVE SUMMARY

E.1 Background

About 40 percent of the Delaware River Basin ("Basin") is located in portions of Pennsylvania and New York underlain by the Marcellus and Utica Shales. The potential for commercially viable natural gas production from these formations within the Basin is not fully known. In regions of Pennsylvania west of the Basin divide, oil and natural gas are extracted from the Marcellus and Utica formations by means of directional drilling and hydraulic fracturing by a process that the Delaware River Basin Commission ("DRBC" or "Commission") refers to as "high volume hydraulic fracturing" ("HVHF"). The South Newark basin formation, which underlies portions of Pennsylvania and New Jersey, may also contain oil and gas deposits capable of development by HVHF. HVHF in combination with directional drilling has been widely used to extract oil and gas from tight rock formations such as shales since around 2008. During HVHF, fluid (generally a blend of large volumes of water mixed with chemicals and sand) is injected through an oil or gas production well into the targeted rock formation under pressures great enough to fracture the hydrocarbon-bearing rock. The hydraulic fracturing fluid carries proppant (typically sand) into the newly created fractures to keep the fractures open. Oil, gas, and wastewater containing contaminants from the fracturing fluid and target formation return up the production well to the surface, where they are collected and managed.

Over the life span of a natural gas development project using HVHF, various activities and incidents pose risks to water resources, including: the withdrawal and consumptive use of large volumes of surface and ground water; spills of harmful chemicals and/or fluids at the surface during chemical mixing of hydraulic fracturing fluid; spills during the collection and transport of returned fluid and produced water; the migration of fluids (including gases) into aquifers and/or surface waters as a result of improperly constructed or deteriorating wells and casings and/ or where natural geologic features create pathways for the migration of fluids (including gases); HVHF wastewater treatment and disposal; and landscape changes associated with HVHF activities. *See,* reports by the New York State Department of Environmental Conservation (NYSDEC, 2015a, 2015b) and the United States Environmental Protection Agency (U.S. EPA, 2016a). NYSDEC's and EPA's findings are supported by extensive additional science-based research, reporting, and data published since 2016.

All of the Basin areas underlain by the Marcellus and Utica Shales, with the exception of a small area of Schuylkill County, Pennsylvania, drain to waters the Commission has designated as "Special Protection Waters" due to their exceptionally high scenic, recreational, ecological, and/or water supply values. The Commission protects the quality of these waters through, among other things, water quality standards and the supplemental requirement in Special Protection Waters "that there be no measurable change [in the quality of these waters] except toward natural conditions." (Water Code, Art. 3 and § 3.10.3 A.2.). The importance of these waters to the public is underscored by their national designation: the non-tidal main stem within and downstream of potential HVHF activity includes 147 river miles designated by Congress as parts of the National Wild and Scenic Rivers System, including 113 river miles that have also been designated as units of the National Park System.

In much of the Basin underlain by hydrocarbon-bearing shales, water users are dependent upon ground water for drinking water and other uses. To protect the quality of the groundwater, since early in its existence the Commission has prohibited the introduction of harmful or toxic concentrations of substances into groundwater. *See,* Water Code § 3.40.5 B.1.

When the potential for developing natural gas from tight shale formations within the Basin using HVHF and horizontal drilling techniques and the risks to water resources posed by such activities became known to the Commission, Commission staff undertook a scientific, technical, regulatory and policy analysis to determine the appropriate response in light of the Commission's statutory mission and Comprehensive Plan. An important milestone occurred on September 13, 2017, when the DRBC Commissioners by a Resolution for the Minutes directed the Executive Director to prepare and publish for public comment a revised set of draft regulations, to include, among other things, "prohibitions relating to the production of natural gas utilizing horizontal drilling and hydraulic fracturing within the basin." In accordance with the Commissioners' September 13, 2017 directive, the Commission proposed amendments to its regulations and Comprehensive Plan which included a prohibition on HVHF within the Basin. *See,* 83 Fed. Reg. 1586 (Jan. 12, 2018).

Extensive opportunity for public input on this proposed rule was provided during the public comment period that took place from November 30, 2017 to March 30, 2018. In addition to accepting written comments, the Commission accepted oral comment at six public hearings, one of which was conducted through an operator-assisted toll-free teleconference to avoid the need for travel to a hearing location. During the comment period, the Commission received a total of 8,903 comment submissions (8,680 in writing and 223 at public hearings). In some cases, one comment "submission" included numerous detailed comments. This response document was prepared and approved by the Commission to address the comments received from the public.

Together with the other materials gathered during the development of its regulation, the Commission reviewed the extensive public comments, including consultant reports, scientific literature and other statements and materials submitted, and examined the experience of other jurisdictions with HVHF.[1] Based upon its review, the Commission found and determined that in other jurisdictions, notwithstanding the existence of regulations and industry best practices, HVHF and related activities have adversely impacted surface and groundwater resources, including drinking water sources and aquatic life, in some regions where these activities have been performed. If commercially recoverable natural gas were present in the Basin, HVHF would likely be employed at numerous well pad sites, primarily in areas that are rural and dependent on groundwater resources, contain sensitive headwaters, or drain to Special Protection Waters. The Basin's geology is characterized by extensive

[1] In keeping with a theme common to many of the comments regardless of perspective—the need for decision making based on scientific data and evidence—the Commission relied upon technical studies and assessments by government agencies, among them: the U.S. Environmental Protection Agency, the National Energy Technology Laboratory, the U.S. Geological Survey, the Pennsylvania Department of Environmental Protection, the New York State Department of Environmental Conservation, and the New York State Department of Health. As discussed extensively in this Comment and Response Document, the Commission also reviewed the large body of evolving scientific literature.

geologic faults and fractures that provide more potential pathways for migration of fluids and gases than exist in many regions outside the Basin.

The Commission further found and determined that if such activities proceeded in the Basin, HVHF-related spills and releases of harmful chemicals and hydraulic fracturing wastewater would likely occur and would pollute surface and groundwater sources and impair their use for drinking water, support for aquatic life and other purposes in the drainage area of Special Protection Waters and across much of the Basin. In addition, well integrity would be compromised, resulting in subsurface fluid and gas migration. The Commission determined that controlling future pollution by prohibiting HVHF in the Basin is required to protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

This Comment and Response Document responds to comments regarding the risks to water resources posed by HVHF, and the potential and observed adverse impacts of HVHF and related activities on water resources. In addition, this document addresses comments concerning: the Commission's authority; the intersection of Commission, state and federal rules; the proposed rule text; basis and background documents; economic impacts; the relationship of HVHF and related activities to DRBC's Comprehensive Plan, rules and policies; public health; chemical disclosures; climate change; renewable energy; policies and reports from the Susquehanna River Basin; the public input process; compliance and enforcement; constitutional challenges and other matters.

Upon adopting its final rules concerning HVHF, the Commission is simultaneously withdrawing proposed Sections 440.4 – Exportation of water for hydraulic fracturing of oil and natural gas wells and 440.5 – Produced Water (and importation of wastewater). The final rules have been revised to eliminate any references to these sections. Public comments specific to sections 440.4 and 440.5 are not addressed in this document. The topics of water exportation and wastewater importation will be addressed as appropriate through one or more separate Commission actions.

E.2 Setting

In reaching its determination to prohibit HVHF within the Basin, the Commission considered the Basin's unique geographic, geologic, hydrologic, and regulatory setting.

The portions of the Basin underlain by the Marcellus and Utica Shale formations are largely located in sensitive headwaters regions of the Basin that are predominantly rural and 85 percent forested, and thereby provide ideal protection for water resources. These areas drain to waters designated and protected by the DRBC as "Special Protection Waters" due to their exceptionally high scenic, recreational, ecological, and/or water supply values, and their inclusion by the United States Congress in the National Wild and Scenic Rivers System.[2]

[2] Section 10 of the Wild and Scenic Rivers Act requires federal agencies to administer designated rivers in a manner that protects and enhances the free-flowing condition, water quality, and "Outstandingly Remarkable Values" for which the river was designated. (*See* Public Law 90-542, Sec. 10.(a), 28 U.S.C. § 1281(a)). Although DRBC is a federal-interstate compact agency, not a federal agency, DRBC's members unanimously agreed to protect the water resource values of this important federally-designated area.

This area also encompasses a portion of northeast Pennsylvania in which 83 percent of river miles and related watershed areas have been designated by the Pennsylvania Department of Environmental Protection as either Exceptional Value (EV) or High Quality (HQ) waters requiring special protection.

The surface and groundwaters that the regulation protects from HVHF impacts provide drinking water to over 13 million people and contain a reservoir system that serves as one of the primary drinking water resources for over 8 million people in the City of New York. The City's three Delaware River Basin reservoirs constitute its largest source of uniquely unfiltered drinking water and are the subject of EPA's Filtration Avoidance Determinations.

Geologically, the area of the Basin underlain by the Marcellus and Utica Shales is characterized by glacial and peri-glacial surficial geology, including moraines, kames, and stratified drifts, that are particularly sensitive to surface disturbances, and are geologically distinct from shale-gas production areas outside of the Basin. The Marcellus and Utica formations generally reach their greatest depths approaching or within the Basin, and then dip steeply upward until they crop out at the Earth's surface in a belt extending through the Basin, creating greater potential for the sub-surface migration of fluids (including gases) into shallow aquifers and ground water than exists in shale-gas settings in central and western Pennsylvania and elsewhere.

The Basin is prone to droughts, water shortages, and salinity intrusion, and the flow of the main stem Delaware River is carefully managed to address these shifting conditions. Climate changes heighten the unique drought and flow management challenges for this Basin.

The statutory framework in the Delaware River Basin Compact ("Compact") provides an institutional mechanism for the four Basin states and the United States to jointly exercise their authorities to manage the Basin's water resources.

E.3 The Rulemaking Framework: The Delaware River Basin and the Comprehensive Plan

In 1961, the United States, the states of Delaware, New Jersey, and New York, and the Commonwealth of Pennsylvania enacted concurrent legislation—the Compact—creating the DRBC to manage the water resources of the Basin.[3] The Compact recognized "the water and related resources of the Basin as regional assets" and established the Commission as an agency through which these vital shared resources could be jointly managed. (Compact, Part 1, Recitals). Water resources include surface water, groundwater and "related natural resources," as well as "related uses of land." (Compact, § 1.2(i)).

The Compact directs the Commission to adopt a Comprehensive Plan "for the immediate and long range development and uses of the water resources of the basin" to which federal, state and local

[3] The federal law enacting the Compact, Public Law 87-328, is set forth in 75 Stat. 688. The laws of the Basin states enacting the Compact are 53 Delaware Laws, Chapter 71; New Jersey Laws of 1961, Chapter 13, New York Laws of 1961, Chapter 148; Pennsylvania Acts of 1961, Act No. 268. http://www.nj.gov/drbc/about/regulations/

agencies and private parties are bound. (Compact §§ 3.2 and 13.1).[4] The Compact provides the Commission with a range of tools for developing and implementing its Comprehensive Plan, including among others, the power to adopt and implement regulations. *See,* Compact, §§ 14.2, 3.6(b), 3.6(h). Article 5 of the Compact grants the Commission authority to, among other things, "adopt and from time to time amend and repeal rules, regulations and standards to control such future pollution and abate existing pollution . . . as may be required to protect the public health or to preserve the waters of the basin for uses in accordance with the comprehensive plan." (§ 5.2).

As this Comment and Response Document shows, HVHF and related activities conflict with elements of the Comprehensive Plan that were adopted to control pollution and protect the Basin's water resources to meet present and future needs.

E.4 Summary of Significant Comments and Responses

The comments the Commission received were wide-ranging and were organized by rule section where appropriate, and then by topic. The topics are listed in the Table of Contents on pages i-ii. Comments and responses concerning the risks to water resources posed by HVHF are addressed initially, followed in a separate section by comments and responses addressing impacts. Although this organization results in some repetition, it allowed the Commission to fully address the potential risks (in Section 2.3.2) resulting from water withdrawals and consumptive use, surface spills during the multiple phases of HVHF and related activities, subsurface migration of contaminants as a result of defective or degraded casing and cementing, problems associated with the handling, treatment and disposal of HVHF wastewater, and widespread landscape changes; and then to focus on the types of impacts (in Section 2.3.3) investigators have observed in drinking water resources, surface waters and aquatic life, groundwater, wetlands and floodplains in connection with HVHF. To reduce the need for repetition, cross-references among the sections are used.

To efficiently capture multiple similar comments, the Commission staff screened and grouped comments with similar themes and from these, developed one or more "statements of concern" within each topic, comprised of paraphrased versions and quotations from one or more comments. Detailed responses, supported by scientific research and data are provided, along with supporting references.

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[4] The Comprehensive Plan contains projects, policies and regulations relating to both water quality and water quantity. Of particular relevance here are provisions establishing water quality standards for surface water, Special Protection Waters for reaches with "exceptionally high scenic, recreational, ecological, and/or water supply values," and measures to protect groundwater resources. *See, e.g.,* Water Code, § 3.10.3 A.2. (adopted by Resolution No. 64-11), and Water Code, § 2.20.5. During the 1970s, by Resolutions Nos. 72-14 and 78-8 the Commission defined groundwater as "all water beneath the surface of the ground" (Water Code*,* § 3.40.2) and identified the uses of these water resources to be protected as "domestic, agricultural, industrial, and public water supplies . . . [and] a source of surface water suitable for recreation, wildlife, fish and other aquatic life." (*Id.* § 3.40.3 A.). The groundwater quality objectives the Commission adopted to support these uses are set forth in Section 1.9 of this Comment and Response Document. The Commission's regulations and Comprehensive Plan also address water quantity. (*See* DRBC Water Code, § 2.5).

Where scientific studies and reports on similar topics sometimes reached different conclusions, the Commission considered the technical strengths and limitations of the studies it reviewed. Because financial relationships between investigators/authors and funding organizations can influence research outcomes in a variety of ways, the Commission also considered these factors. The Commission based its conclusions on: the collective weight of the available scientific studies, research and evidence; the assessments and studies completed to date by federal and state agencies; the Basin's unique geologic, hydrologic and regulatory setting; and the requirements of the Compact and the Comprehensive Plan.

E.4.1 Significant Risks to Water Resources

The Comment and Response Document contains the Commission's responses to comments regarding the significant risks of HVHF on water resources.

SPILLS: Scientific evidence has shown that spills during HVHF activities present significant risks to surface waters and groundwater resources. EPA has identified spills as among the incidents most likely to result in contamination of drinking water resources (U.S. EPA, 2016a, p. ES-37).

Substantial quantities of chemicals, additives and agents (such as biocides, corrosion inhibitors, friction reducers, scale inhibitors, and degreasers) are typically used in the water-based fracturing fluid injected into an unconventional oil or gas well during HVHF (*Id.,* Table 5-1). Among the chemicals typically used, many are known carcinogens, and the toxicity of many others is unknown. (*Id.*, p. 9-22). In addition to these potential pollutants, the fluid returned from an oil or natural gas well after HVHF (typically called produced water) is mixed with water from the target formation, containing: salts, including chloride, bromide, sulfate, sodium, magnesium, and calcium; metals, including barium, manganese, iron, and strontium; naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, and xylenes (BTEX), oil and grease; and radioactive materials, including radium (*Id.*, Table 9-4). Thus, spills of chemicals, fracturing fluids or produced water present significant risk.

Spills may occur during every phase of the hydraulic fracturing process—on or near the well pad during drilling and completion of a natural gas well; during the mixing, injection, recovery and storage of fracturing fluids and formation water (the most often cited source of HVHF spills); and during the production stages of shale gas development. The potential distribution of HVHF operations across the landscape in the Basin, coupled with the need to transport raw materials and wastes to and from remote pad sites, often on temporary and unpaved roads which may be unsuitable for heavy industrial traffic, raise the potential for spills to reach and contaminate sensitive environmental receptors, including wetlands, ponds and lakes, and streams. Spills and releases of chemicals, hydraulic fracturing production fluids, and wastewaters represent a greater and unique risk to water resources when compared with chemical and wastewater spills of many other industries and activities. The combination of the characteristics of the materials and technologies involved, the diffuse nature of well pad siting, the mobility and dispersal of materials, personnel, vehicles and equipment transferred to and from these sites, and the proximity of drilling locations to sensitive environmental features, including the drainage area of the non-tidal river and the headwaters of Special Protection Waters, is unlike any other industry.[5]

The past decade of experience with HVHF in Pennsylvania and other regions has shown that regulation is not capable of preventing releases due to spills and subsurface migration of harmful HVHF pollutants.

FLUID MIGRATION: The weight of the evidence shows that HVHF and related activities can and have resulted in the migration of HVHF fluids (including gases) through artificial and/or natural pathways, with adverse impacts on water resources.

In northeastern Pennsylvania, where geologic conditions, including extensive faults and fractures, are different from and more complex than tectonically tranquil shale gas settings, the probability of fluid migration may be substantially higher, especially in cases in which well integrity is compromised.

Despite advances in industry standards, recommended practices and techniques, and state regulations, problems with gas well integrity persist. Inadequate well integrity resulting from casing or other equipment failure, inadequate or deteriorating cement in the annular spaces of the wellbore, or both, is usually the cause of documented migration of fluids (including gases) from HVHF activity.

Technical problems during the complex process of cementing gas wells have plagued the industry for decades, have not been resolved through regulations or industry standards, and may result in fluid migration throughout the life cycle of the natural gas well.

WASTEWATER TREATMENT AND DISPOSAL: Hydraulic fracturing wastewater (defined in Appendix-2) may contain a complex blend of constituents, including among others, those listed in the discussion of spills above. As of 2013, nearly 1.6 billion gallons of wastewater had been generated in the process of extracting natural gas from shale in Pennsylvania (Rahm *et al.,* 2013). In 2014, 87 percent of this wastewater was recycled and reused in the hydraulic fracturing process, about 10 percent was disposed at regulated underground injection wells, and 2.3 percent was treated at wastewater treatment facilities and discharged to surface waters (Veil, 2015; Yoxtheimer, 2014). The volume of HVHF produced water (defined in Appendix-2) is expected to increase over time in Pennsylvania.

Despite the availability of advanced technologies for treating oil and gas wastewater before discharge, these technologies are not widely utilized in Pennsylvania wastewater treatment plants that discharge to surface waters, and elevated concentrations of wastewater components have been

[5] Certain commenters asserted that the Commission's implementation of its rulemaking authority here raises Constitutional concerns. Particularly in light of the unique features of the Basin described in Section E.2 and the characteristics of this industry, addressing HVHF activities differently from activities posing less risk to water resources is a proper exercise of DRBC's authority. Likewise, in light of the risks posed by HVHF, and considering other economically viable uses for properties containing natural gas, the prohibition does not result in a compensable "taking" of property. These and other legal issues are discussed in Section 2.1.1 and 2.6.10 of this Comment and Response Document.

detected downstream of centralized wastewater treatment facilities treating HVHF wastewater (U.S. EPA, 2018b).

If the risks posed by, and impacts from, HVHF wastewater treatment and disposal alone or in combination with the risks and adverse effects of consumptive water use and landscape changes[6] were the only water resource concerns, it might be possible to manage them effectively through regulation without prohibiting HVHF activities. However, they enlarge the totality of the risks to water resources from spills and subsurface gas and fluid migration that would accompany HVHF and related activities within the Basin. In light of the totality of risks, vulnerabilities, and anticipated impacts, controlling future pollution from these activities by prohibiting HVHF in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

E.4.2 Significant Impacts to Water Resources

The risks posed by HVHF activities have resulted in adverse impacts to water resources in areas in which HVHF has occurred. Because of the conditions in the Basin discussed in the "Settings" and other sections above, the impacts within the Basin would likely be more severe than in other locations at which HVHF has occurred. The potential water resource impacts discussed in this Comment and Response Document are as follows:

DRINKING WATER RESOURCES: Groundwater and surface water sources used for public and private drinking water supplies are vulnerable to the risks posed by HVHF and related activities, including releases of chemicals and highly contaminated fluids from spills and accidents; migration of fluids including gases; inadequate wastewater treatment; improper wastewater storage or disposal; short- and long-term landscape changes; wastewater reuse on roadways; excessive aquifer drawdown and reduced yield; localized stream depletion; and removal of significant quantities of water through consumptive use, especially during periods of low precipitation or drought.

The weight of the evidence shows that HVHF activities have adversely impacted private water supply wells, and proximity to gas wells is an important factor in the likelihood of such impacts. Well-documented cases of private well impacts are discussed in Section 2.3.3.1 of this Comment and Response Document. As discussed in that Section, since 2008, the Pennsylvania Department of Environmental Protection (PADEP) has identified 356 cases (through September 22, 2020) that resulted in PADEP's issuance of a Water Supply Determination Letter stating that a water supply (in some instances affecting multiple users) was impacted by conventional or unconventional oil and gas activities.

New York State has recognized that impacts from HVHF activities, if allowed in the New York City reservoir watershed in the Basin, would pose unacceptable risks to drinking water (NYSDEC, 2015a). In addition, New York State has determined that HVHF should not proceed within that state until

[6] The contributions of consumptive water use and landscape changes to the totality of risks posed by HVHF and related activities are discussed in Sections 2.3.2.1 and 2.3.2.5 of this Comment and Response Document.

science provides sufficient information to determine the level of risk to public health and whether the risks can be adequately managed (NYSDOH, 2014).
The Commission agrees with the conclusions of the 2016 EPA assessment report that hydraulic fracturing can impact drinking water resources and that the resource vulnerabilities related to hydraulic fracturing identified in the report can vary in frequency and severity depending upon multiple factors that are both within and beyond human control. EPA recognized that scientific information presented in its report can help inform decisions by federal, state, tribal and local officials, industry and communities. (U.S. EPA, 2016a, pp. ES-3, ES-4). The Commission has determined that HVHF has and will continue to impact public and private drinking water resources outside the Basin and that controlling future pollution by prohibiting HVHF in the Basin is required to protect drinking water sources within the Basin as contemplated by the Comprehensive Plan.

AQUATIC LIFE: Risks to water resources from HVHF and related activities occur at each stage of the hydraulic fracturing water cycle, including water acquisition, chemical mixing, well injection, produced water handling and wastewater disposal and reuse (EPA, 2016a, p. ES 9). Many of these activities are also risks to aquatic life. Results of numerous laboratory and scientific field research studies discussed in Section 2.3.3.2 of this Comment and Response Document provide strong evidence that HVHF activities have resulted in substantial and persistent impacts to surface waters and aquatic life, including threatened and endangered species. Section 2.3.3.2 also identifies numerous spill incidents that occurred during various stages of the HVHF water cycle that have impacted surface water, wetlands, and/or aquatic life including fish and amphibians. Evidence of endocrine disruption in surface water samples associated with HVHF activity observed in Pennsylvania, Colorado, West Virginia, and North Dakota is also discussed in Section 2.3.3.2.[7] In addition, aquatic trophic structure and mercury biomagnification dynamics were shown to be affected by the presence or absence of unconventional well development in the watersheds of twenty-seven remotely located streams in the Pennsylvania Marcellus Shale region (Grant *et al.,* 2016). EPA has documented spills of HVHF flowback, produced water, and chemicals in Texas and Pennsylvania that impacted wetlands (U.S. EPA, 2015e, App. B).[8]

Despite existing regulations, HVHF and related activities have and will continue to impact aquatic life at locations outside the Basin. Controlling future pollution by prohibiting HVHF in the Basin is required to protect aquatic life in the waters of the Basin.

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[7] With respect to surface waters, results of SRBC's 2016 and 2019 monitoring reports have been largely misreported as demonstrating no impact on surface water quality as a result of hydraulic fracturing. SRBC itself and other authoritative sources, including the 2016 Northeast-Midwest Institute and U.S. Geological Survey report, likewise emphasized that the SRBC monitoring results are inconclusive. (Hintz and Markowitz, 2016, p. 14; Berry *et al.*, 2019; Betanzo *et al.*, 2016). In addition, the SRBC data do not comprehensively or definitively address the question of long-term impacts to water resources. Details of known impacts to water resources in the Susquehanna River Basin from high volume hydraulic fracturing activities, including impacts to private drinking water wells, are provided in Section 2.3.3 of this document.

[8] Effluent from centralized waste treatment facilities treating HVHF wastewater has resulted in persistent sediment contamination many miles downstream and impacted surface water quality and aquatic life, although new regulations and recent actions by the PADEP have greatly curtailed the discharge of effluent from CWT facilities treating HVHF wastewater in Pennsylvania. (*See* Appendix-4).

LANDSCAPE CHANGES AND WATER USE: HVHF activities cause changes to the landscape such as destruction of forested cover. (Slonecker *et al.*, 2012, p. 23; NYDEC, 2015a, p. 6-76). In the Basin, these changes would occur primarily within the drainage area of DRBC Special Protection Waters. Forest complexes provide substantial water resource benefits. In addition, consumptive use of water for hydraulic fracturing is permanently removed from the hydrologic cycle, presenting risks of stream depletion and diminution of groundwater supplies especially during periods of drought and low flow. Although the severity of likely impacts from landscape changes and water use is relatively low when compared with other likely impacts from other risks described in this document, landscape changes and water use contribute to the totality of the water resource impacts that accompany HVHF and related activities to the water resources of the Basin.

E.4.3 Other Comments

COORDINATION WITH STATE AND FEDERAL REGULATIONS: Several commenters questioned the need for separate regulation of HVHF by the DRBC, arguing that state and federal regulations as well as industry best management practices adequately protect against potential adverse impacts to water resources. Based on an extensive scientific and technical analysis, the Commission concluded that these regulations would not be adequate to protect the water resources of the Basin from the risks of HVHF activities in light of the Basin's setting described above and other circumstances detailed in this Comment and Response Document.

ECONOMIC IMPACT: The Commission requested and received several comments regarding the potential for statewide and regional economic impacts that could result if HVHF were to be prohibited within the Basin. Natural gas extraction using HVHF can present opportunities for economic gains.

The American Petroleum Institute ("API") submitted a detailed statewide and regional economic analysis prepared by a consultant. The Commission has carefully reviewed the report and has considered its findings, as well as those of peer-reviewed studies on the economic impacts of hydraulic fracturing. The Commission's review of the API report found many of its assumptions to be flawed and that the net economic benefits of hydraulic fracturing in the Basin would likely be substantially less than those the API's consultant projected.

Many commenters also suggested that HVHF would permanently harm the unique character of the Basin and result in adverse impacts to existing economic drivers in the region such as agriculture, recreation and eco-tourism, diminishing the quality of life that basin residents currently enjoy. The Commission found that supporting studies that outlined annual economic natural resource value estimates for large areas of the Basin or for large industries in the Basin (such as tourism, boating, summer camps, fishing, hunting, wildlife viewing, swimming, and skiing) had flawed assumptions or implications as well.

The review and consideration of the comments received, and related economic studies were used by the Commissioners to help inform their decision-making regarding the proposed rules.

OTHER: Several other topics related to the proposed rules are addressed in this Comment and Response Document. Those topics included: public health, chemical disclosure, climate change, renewable energy, Susquehanna River Basin policies, the public input process, the need for compliance and enforcement, the need to protect other recreational, agricultural, commercial and industrial uses, and legal issues. To the extent they are relevant to the current rulemaking, the Commission considered these comments and provided responses in Section 2.6.

The Commission received additional comments concerning air emissions, natural gas pipelines, earthquakes, non-aquatic wildlife, natural gas storage, underground injection wells, brine road applications and miscellaneous topics that were not subjects of this rulemaking. These comments are acknowledged in Section 2.7 but do not provide a basis for the current rule.

E.5 Findings and Determinations in Support of Final Rule

Pursuant to the authority conferred on the Delaware River Basin Commission by its organic statute, the Delaware River Basin Compact, the Commission by Resolution No. 2021-01 (*see* full text in Appendix-1), made the findings and determinations set forth below:

1. As the scientific and technical literature and the reports, studies, findings and conclusions of other government agencies reviewed by the Commission have documented, and as the more than a decade of experience with high volume hydraulic fracturing in regions outside the Delaware River Basin have evidenced, despite the dissemination of industry best practices and government regulation, high volume hydraulic fracturing and related activities have adversely impacted surface water and groundwater resources, including sources of drinking water, and have harmed aquatic life in some regions where these activities have been performed.

2. The region of the Delaware River Basin underlain by shale formations is comprised largely of rural areas dependent upon groundwater resources; sensitive headwater areas considered to have high water resource values; and areas draining to DRBC Special Protection Waters.

3. The geology of the region in which shale formations potentially containing natural gas are located in the Basin is characterized by extensive geologic faults and fractures providing preferential pathways for migration of fluids (including gases).

4. If commercially recoverable natural gas is present in the Delaware River Basin and if high volume hydraulic fracturing ("HVHF") were to proceed in the Basin, then:

    a. Spills and releases of hydraulic fracturing chemicals, fluids and wastewater would adversely impact surface water and groundwater, and losses of well integrity would result in subsurface fluid (including gas) migration, impairing drinking water resources and other uses established in the Comprehensive Plan.

    b. The fluids released or migrating would contain pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined, impairing the water uses protected by the Comprehensive Plan.

c. HVHF activities and their impacts would be dispersed over and adversely affect thousands of acres of sensitive water resource features, including, among others, forested groundwater infiltration areas, other groundwater recharge locations, and drainage areas to Special Protection Waters, where few existing roads are designed to safely carry the heavy industrial traffic required to support HVHF, prevent dangerous spills or provide access to remediate spills that occur.

5. For the foregoing reasons and other grounds described in the administrative record for this rulemaking:

   a. High-volume hydraulic fracturing and related activities pose 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, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values.

   b. Controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

1. INTRODUCTION

1.1 Background

About 40 percent of the geographic area of the Delaware River Basin (“Basin”) in portions of Pennsylvania and New York is underlain by the Marcellus and Utica Shales (*see* Figure 1). Although the presence of commercially viable natural gas from these formations within the

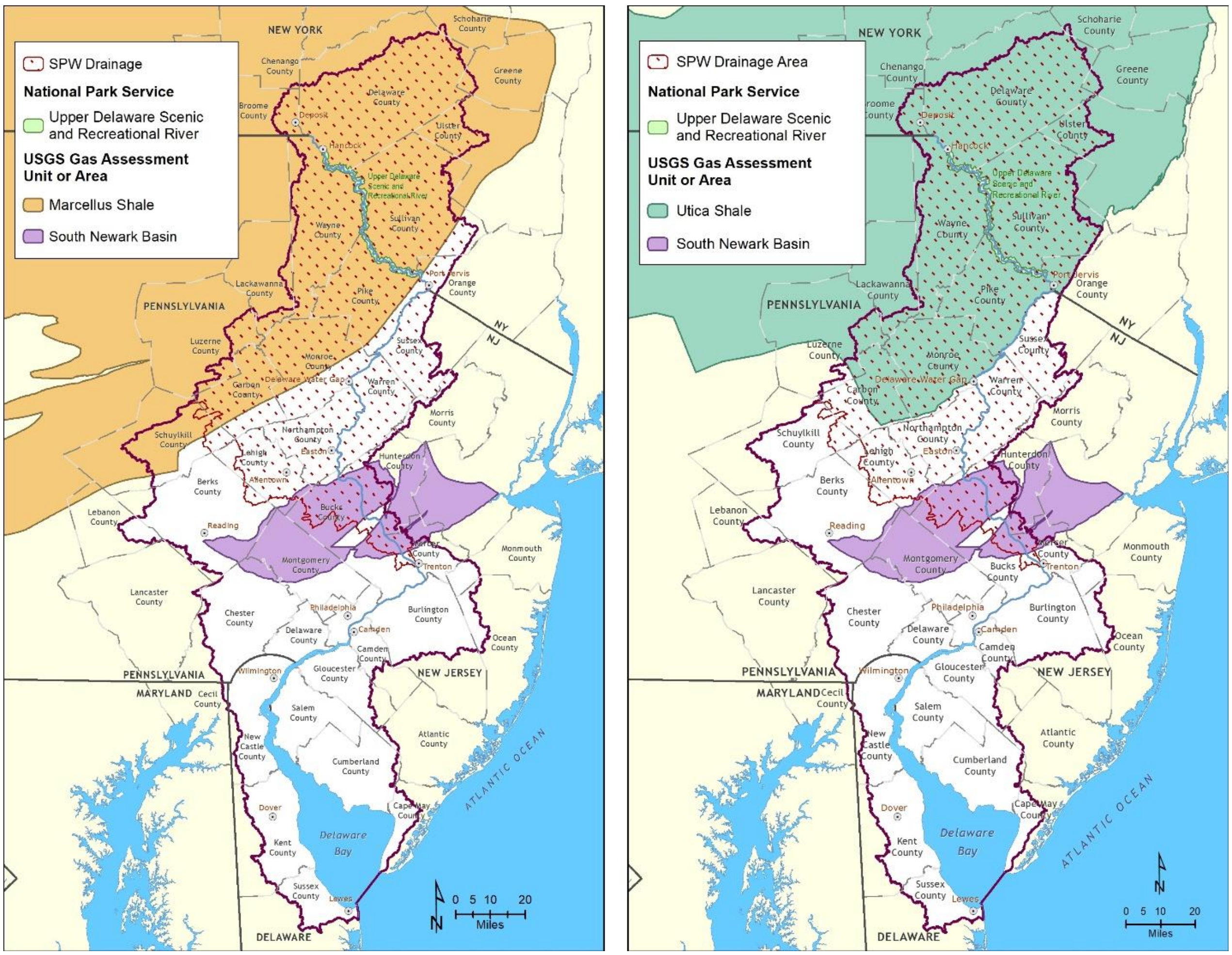

Figure 1: Gas Assessment Units in the Delaware River Basin
Sources: Higley, 2019; Enomoto and Schenk, 2019; USGS, 1996

Basin is not known, in regions of Pennsylvania west of (but not immediately adjacent to) the Basin divide, oil and natural gas are extracted from the Marcellus and Utica formations by means of directional drilling and hydraulic fracturing using large volumes of water and generating large volumes of toxic wastewater in a process referred to as “high volume hydraulic fracturing” (“HVHF”). The South Newark basin, which underlies portions of Pennsylvania and New Jersey, may also contain oil and gas deposits capable of extraction using HVHF. All of the basin areas underlain by the Marcellus and

Utica Shales, with the exception of portions of Schuylkill County, Pennsylvania, drain to waters the Delaware River Basin Commission ("DRBC" or "Commission") has designated as "Special Protection Waters," due to their exceptionally high scenic, recreational, ecological, and/or water supply values. The Commission's water quality management policy objective for Special Protection Waters is "that there be no measurable change [in the quality of these waters] except toward natural conditions."

On September 13, 2017, the Commission by Resolution for the Minutes directed the Executive Director to prepare and publish for public comment a revised set of draft regulations, to include: "(a) prohibitions relating to the production of natural gas utilizing horizontal drilling and hydraulic fracturing within the basin; (b) provisions for ensuring the safe and protective storage, treatment, disposal and/or discharge of wastewater within the basin associated with horizontal drilling and hydraulic fracturing for the production of natural gas where permitted; and (c) regulation of the inter-basin transfer of water and wastewater for purposes of natural gas development where permitted."

Through the adoption of a series of policies and regulations establishing and amending its Comprehensive Plan, the Commission over the past half-century has developed and implemented in-stream water quality standards throughout the Basin, prohibited degradation of groundwater, and provided special protection to the non-tidal portion of the Delaware River to preserve the exceptionally high water quality and water supply values of this resource. As the agency through which the five signatory parties to the Compact—the States of Delaware, New Jersey and New York; the Commonwealth of Pennsylvania; and the Federal Government—collectively manage the Basin's water resources on a regional basis, the Commission has taken these steps to, among other things, ensure an adequate supply of suitable quality water for domestic use, recreation, power generation, industrial activity and aquatic life, and to accommodate large out-of-basin diversions by the City of New York and the State of New Jersey that are authorized by the 1954 decree of the U.S. Supreme Court in *New Jersey v. New York*, 347 U.S. 995.

In accordance with the Commissioners' directive of September 13, 2017, the Commission in November 2017 proposed amendments to its regulations and Comprehensive Plan in connection with the hydraulic fracturing of shale and other hydrocarbon bearing formations to produce natural gas. To effectuate the Comprehensive Plan for the immediate and long-term development and use of the water resources of the Basin, the rules prohibit high volume hydraulic fracturing within the Basin. Proposed rule amendments, a Notice of Proposed Rulemaking, and a link to the public comments received can be found on the Commission's web site at:

- https://www.nj.gov/drbc/meetings/proposed/notice_hydraulic-fracturing.html

A summary of Commission actions with respect to hydraulic fracturing for oil and gas extraction prior to the Commission's September 13, 2017 directive is available at:

- https://www.nj.gov/drbc/programs/natural/archives.html and
- https://www.nj.gov/drbc/programs/natural

1.2 Public Input Purpose and Process

Multiple opportunities for public input on this rulemaking were provided during a 120-day comment period that ran from November 30, 2017 through March 30, 2018. Written comments were accepted throughout the comment period through an on-line comment intake system. An exception process was provided for those who lacked access to the on-line system or were otherwise unable to use it. The Commission received just two (2) requests for exceptions and approved both (although only one of the two requesters ultimately submitted comments outside the system).

Opportunities for oral comment included six public hearings, the dates, times, and locations of which are listed below. The final public hearing in March of 2018 was conducted by means of an operator-assisted, toll-free teleconference, allowing participants to comment orally without traveling to a hearing location.

1. January 23, 2018, 1 p.m., Waymart, Wayne County, PA
2. January 23, 2018, 6 p.m., Waymart, Wayne County, PA
3. January 25, 2018, 1 p.m., Philadelphia, PA
4. January 25, 2018, 6 p.m., Philadelphia, PA
5. February 22, 2018, 3 p.m., Schnecksville, PA
6. March 6, 2018, 1:30 p.m., via toll-free teleconference.

In all, the Commission received 223 oral comments during its six public hearings. Every person who wished to speak at each of the six hearings was afforded an opportunity to do so. Some individuals spoke at more than one public hearing, and many of those who offered oral comment also submitted comments in writing. Transcripts of the public hearings, and all of the written comments received during the comment period are available for inspection on the DRBC web site at:

- https://www.nj.gov/drbc/meetings/proposed/notice_hydraulic-fracturing.html (Public Hearing Transcripts)
- http://dockets.drbc.commentinput.com/?id=PGChb (Written Comments)

In its Notice of Proposed Rulemaking, the Commission expressly invited the public to comment on the effects the proposed rules might have within the Basin on: water availability, the control and abatement of water pollution, economic development, the conservation and protection of drinking water supplies, the conservation and protection of aquatic life, the conservation and protection of water quality in Special Protection Waters, and the protection, maintenance and improvement of water quantity and quality Basin-wide. Comment was expressly requested on whether the use of base fluids other than water for hydraulic fracturing is practical within the Basin, and if so, how HVHF using alternative fluids should be addressed in the rules. Commenters were also asked to identify alternatives to the proposed rules that the Commission should consider and were asked to comment on draft guidance published simultaneously with the rules for determining background concentrations of certain pollutants. The Commission encouraged submission of any other comments concerning the potential effects of the draft rules on the conservation, utilization, development, management and control of the water and related resources of the Delaware River Basin. The public was informed that comments on matters not within the scope of the rules might not be considered.

The Commissioners, in consultation with the DRBC staff, carefully reviewed and considered all of the public's comments before voting to adopt and incorporate them into the Comprehensive Plan in accordance with the Delaware River Basin Compact.

1.3 Overview of Comment Submissions

During the comment period the Commission received a total of 8,903 comment submissions as follows:

- 8,679 written submissions through the Commission's on-line intake system
- 223 oral submissions at six public hearings
- 1 set of written comments in hard copy, through the exception process.

In some instances, one comment "submission" included one specific comment. In other instances, one "submission" included numerous detailed comments or a collection of comments by multiple individuals or entities. Commenters had the opportunity to include attachments and references with their comments, and these at times included hundreds, or even thousands, of pages of information. While most comments were submitted by organizations and individuals located in geographic areas within or near the Delaware River Basin, as shown in Figure 2, comments were submitted from every region of the United States as well.

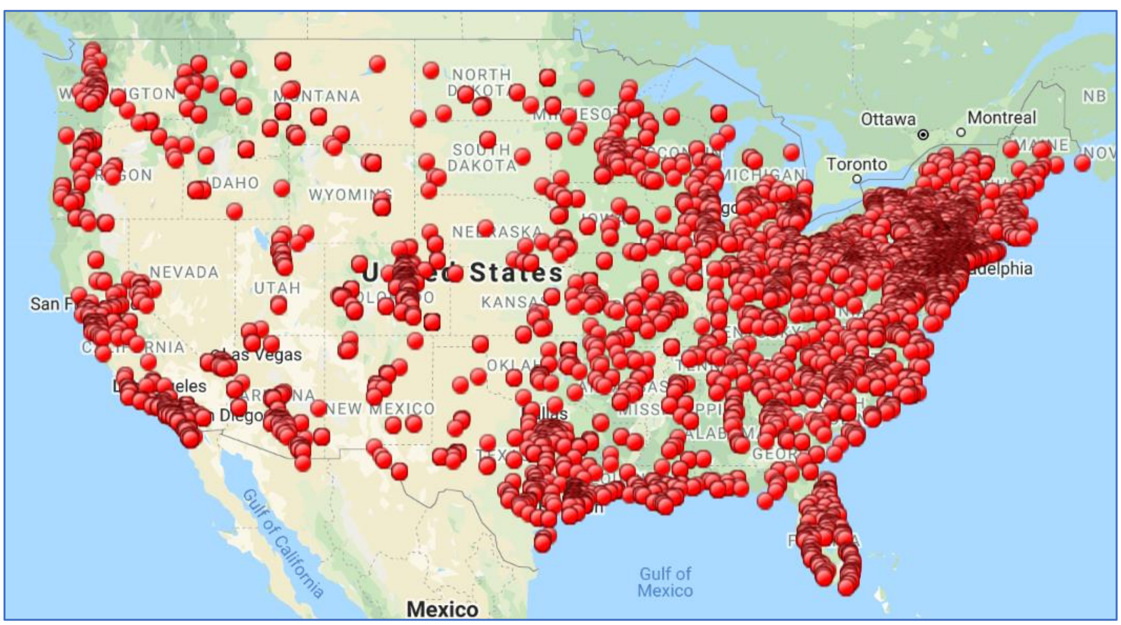

Figure 2: Location of comment submissions from the "Lower-48" United States

Several "types" of comments were received. About 76 percent of all submissions consisted of form letters prepared by organizations but signed and in many instances personalized by individuals. Figure 3 shows the number of comment submissions received by the "type" of comment.

The Commission received 14 petitions containing a combined total of 42,049 signatures, calling for a "complete ban" on hydraulic fracturing within the Delaware River Basin. No attempt was made to purge duplicate signatures or to analyze where the signatories resided, although both basin residents and non-residents were represented. The Commission also received 26 municipal government resolutions during the comment period.

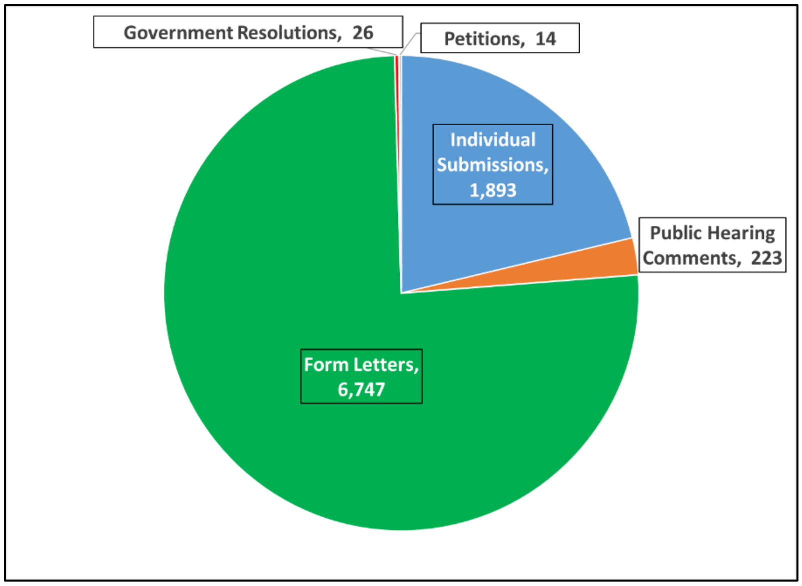

Figure 3: Comment Submissions by Type

Notably, the Commission received numerous comments before the comment period opened, and it continued to receive comments and resolutions (though much fewer) after the comment period closed. In general, no significant "new issues" were raised after the close of the comment period. Some individuals and organizations sent the Commission additional studies that were published after the comment period closed. Since the science on the effects of HVHF on water resources and the environment is evolving, the Commission has continued independently to review and consider published research that it deems relevant to its proposed action.

1.4 Organization of Comments and Responses

This comment response document is generally organized by proposed rule section. In some cases, comments span multiple rule sections, and in those cases, responses may be repeated, referenced to another section or responded to in a general summary response. In almost all cases, comments submitted by various individuals and organizations were similar in theme to comments submitted by others. As such, the Commission staff reviewed all comments and then screened and grouped comments with similar themes into "statements of concern." Each "statement of concern" is a consolidated paraphrased version of one or more comments on a shared theme. The Commission has responded to each statement of concern. The process of screening, grouping, paraphrasing and organizing comments for response is depicted in Figure 4.

The Commission received numerous comments on subjects outside the scope of the rules, and in some cases, outside the scope of the Commission's authority as defined by the Delaware River Basin Compact. To provide the Commissioners with a complete and comprehensive view of the comments received, the staff developed statements of concern for these comments. In some cases, responses to these out-of-scope submissions are provided; however, in many cases the Commission's response simply notes that the comments are beyond the scope of the proposed action.

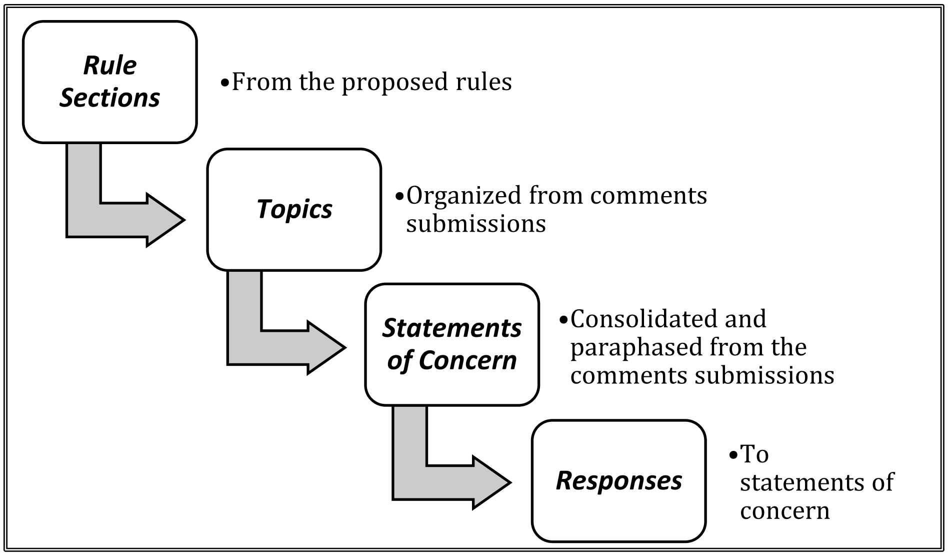

Figure 4: Organization of comment submissions and responses

1.5 Withdrawal of Proposed New Sections 18 C.F.R. §§ 440.4 and 440.5

The Commission is withdrawing proposed Section 440.4 - Exportation of water for hydraulic fracturing of oil and natural gas wells, and proposed new Section 440.5 - Produced Water (and importation of wastewater). The final rules have been revised to eliminate both sections and any references to them in other proposed new or amended sections. Public comments specific to sections 440.4 and 440.5 are not addressed in this document. The topics of water exportation and wastewater importation will be addressed through one or more separate Commission actions.

1.6 Water Resources of the Delaware River Basin

The Delaware River Basin occupies 13,600 square miles in a densely populated corridor of the northeastern U.S. (*see* Figure 5) and stretches approximately 330 miles from the river's headwaters in New York State to the Atlantic Ocean. The Basin encompasses parts of Pennsylvania (6,422 square miles or 50.3 % of the Basin's total land area); New Jersey (2,969 square miles, 23.3%); New York (2,362 square miles, 18.5%); and Delaware (1,002 square miles, 7.9%). The area of Delaware Bay adds 782 square miles of water surface to the Basin.

The Delaware River, undammed from the confluence of its East and West Branches at Hancock, New York to the mouth of Delaware Bay, is the longest "free-flowing" river in the eastern U.S. Its flow is augmented by over 2,000 tributaries, of which many are rivers in their own right. The largest are the Schuylkill and Lehigh Rivers in Pennsylvania. The northernmost tributaries to the Delaware River originate in the forested western slopes of the Catskill Mountains, which reach elevations of up to

4,000 feet. The East and West Branches meet at Hancock, New York, where the main stem Delaware River begins. The River descends about 800 feet on its journey from the headwaters to the Atlantic Ocean.

Although the Basin drains only four-tenths of one percent of the total continental U.S. land area, its water resources provide drinking water for over 13.3 million people in four states—approximately 4 percent of the total population of the United States.

On the basis of physical characteristics, the Basin may be divided roughly into three physiographic regions—the Upper, Central and Lower regions.

Figure 5: The Delaware River Basin

The highlands of the southern Catskill and Pocono Mountains dominate the Upper Region. The Basin's maximum elevation of 4,200 feet occurs here. Geologically, the region is part of the "hard" rock area where bedrock is resistant to erosion. It is almost completely forested, with mixed hardwoods predominating, contains high-quality cold-water streams, and is almost totally glaciated. The Upper Region exhibits the characteristics of a plateau of flat-lying rocks cut by narrow valleys that have been deeply carved by the river and its tributaries. The Delaware River emerges from the confluence of the southwesterly-flowing East Branch and West Branch tributaries, at Hancock, New York. New York City's Department of Environmental Protection (NYCDEP) owns and operates two large public water supply reservoirs on the East and West Branches, respectively—Pepacton and Cannonsville. The drainage areas to these reservoirs and a third New York City Delaware Basin reservoir, the Neversink, are highly managed by NYCDEP's watershed protection program. From Hancock southeastward to Port Jervis, New York the Delaware River divides Pennsylvania and New York. In this reach, the main stem receives flows from three important tributaries—the Lackawaxen, Mongaup and Neversink rivers—each of which has been dammed to create a hydroelectric and/or public water supply reservoir.

The Upper Region has two prominent water resource management features. First is the exportation from the Pepacton, Cannonsville and Neversink reservoirs of up to 800 million gallons per day (mgd) of basin water to New York City in accordance with a U.S. Supreme Court Decree issued in 1954 (the "Decree"). The second is the exceptional quality of the surface waters of the region. In 1978, under the Wild and Scenic Rivers Act, Congress designated 73.4 miles of the Delaware River in the Upper

Region as a unit of the National Park System and a component of the National Wild and Scenic Rivers system. In 1992, DRBC designated most of the main stem in the Upper Region as "Outstanding Basin Waters," affording these waters the highest level of protection available under the Commission's Special Protection Waters program. Groundwater resources of the Upper Region are present primarily in fractured rock aquifers. Unconsolidated valley-fill aquifers are also present in some areas. Most residents of the Upper Region depend on these groundwater resources for drinking water supplies.

Turning southwestward at Port Jervis, the main stem Delaware River enters the Central Region, where it becomes the dividing line between New Jersey and Pennsylvania. Under the Decree, the Delaware River Master coordinates releases from New York City's reservoirs in the Upper Region to meet an instream flow objective measured at the U.S. Geological Survey's Montague, New Jersey gage. The Central Region extends through an upper section that comprises part of the Valley and Ridge physiographic province, with its pattern of parallel ridges running northeast to southwest, and a lower section—the Piedmont—characterized by low rolling hills and complex rock formations. The Central Region is bounded on the southeast by the Fall Line, where the land drops abruptly by 250 to 350 feet to the Atlantic Coastal Plain. Important physiographic features of the Central Region include the Blue Mountain–Kittatinny Mountain Ridge, and the Great Valley, extending northeast–southwest across the Basin. Like the Basin's Upper Region, the Central Region lies in the "hard" rock area, but only its northeast portion has been glaciated. About a third of the land area is forested, and rich soils support agricultural activities in many areas. The Delaware River flows in a narrow valley between the Shawangunk Mountains on the east and the Appalachian Plateau on the west. Near Stroudsburg, Pennsylvania, the main stem cuts to the southeast through the Blue Mountain–Kittatinny Mountain Ridge at the Delaware Water Gap. Significant tributaries such as the Bushkill and Brodhead Creeks and the Flatbrook River join the Delaware just above the Water Gap.

The most prominent water resource management feature of the Central Region is the continued exceptional quality of the main stem Delaware River. In 1978, Congress created the 70,000-acre Delaware Water Gap National Recreation Area, managed by the National Park Service. Thirty-five miles of the main stem Delaware River in this region were designated by Congress as National Scenic River, and an additional 5 miles as National Recreational River. In 1992, the Commission classified most of the main stem Delaware River from Milford, Pennsylvania to the Delaware Water Gap as Outstanding Basin Waters under the DRBC's Special Protection Waters program. Downstream of the Water Gap significant tributaries, including the Lehigh, Paulins Kill, Beaver Brook, Pequest and Musconetcong Rivers, enter the main stem. In 2000, approximately 67 miles of the main stem Delaware River from just below the Water Gap to Washington Crossing, Pennsylvania, and portions of three tributaries to this reach were added to the National Wild and Scenic Rivers System. Significant portions of the Musconetcong River were added in 2006. In 2005, DRBC classified most of the main stem Delaware River from the Water Gap to Trenton, New Jersey as "Significant Resource Waters" under the Commission's Special Protection Waters program. Within this reach of the main stem, the out-of-basin diversion by New Jersey approved by the 1954 Decree begins at Bulls Island. The Decree allows the state to export up to 100 mgd of water from the Basin through the Delaware and Raritan Canal for use in northern and central New Jersey. At the bottom of the Central Region, the Fall Line forms an irregular south-facing escarpment between the undulating plateau and the Coastal Plain, passing through Trenton, New Jersey and Wilmington, Delaware. Groundwater resources of the Central Region are present primarily in fractured rock aquifers. Unconsolidated valley-fill aquifers are also present in some areas.

At Trenton, New Jersey, the River enters the Lower Region, or tidally influenced portion of the Basin. The Lower Region covers the area from the Fall Line to the capes (Cape Henlopen and Cape May), where Delaware Bay meets the Atlantic Ocean. Physiographically, the Lower Region consists of the emerged part of the Atlantic Coastal Plain, a gently sloping surface extending 125 to 175 miles southeasterly from the Fall Line to the Continental Shelf. Geologically, the region is a "soft" rock area composed of overlapping beds of unconsolidated or semi-consolidated clay, silt, sand and gravel. The Delaware Bay is the Lower Region's most marked water feature. About one-third of the land area is wooded, with about equal division between soft and hard woods. The soil supports a variety of important agricultural activities. Turning southwest from Trenton, the River's course parallels the Fall Line to Wilmington, receiving the flows of the Neshaminy, Schuylkill, Rancocas and Christina tributaries along the way. Just below Wilmington the River turns seaward and flows to Liston Point, where it enters Delaware Bay.

The Lower Region contains the most heavily populated areas of the Basin, including the cities of Trenton, Philadelphia, Camden and Wilmington along the I-95 corridor. The tidal Delaware River, or "estuary," in the uppermost portion of the Lower Region is marked by a legacy of industrial and municipal wastewater pollution. Where conserving high water quality is a management objective for the non-tidal river (upstream from Trenton), the focus here is on pollution abatement and water quality improvement. Although tidal, the Lower Region also contains the majority and largest of the Basin's surface water withdrawals for public water supply. During dry periods, freshwater flows into the Lower Region are augmented by the DRBC with releases from storage reservoirs upstream to protect these large surface water intakes from saltwater intrusion. DRBC staff monitor the U.S. Geological Survey's flow gage at Trenton to ensure target flows to the Delaware River Estuary are maintained. In addition, two areas of groundwater withdrawal stress are located and managed in the Lower Region.

The main stem Delaware River in the Lower Region is modified by a navigational channel dredged to a depth of 45' as far inland as Philadelphia, allowing oceangoing vessels into the ports of Wilmington, Camden and Philadelphia. The channel extends upstream from Philadelphia to Bordentown, New Jersey at a depth of 40', and from Bordentown to Trenton at 35'. The Chesapeake and Delaware Canal connects the Delaware River below Wilmington, Delaware with Chesapeake Bay. The Canal is also navigable by oceangoing vessels. Groundwater resources of the Lower Region are present primarily in fractured rock aquifers and unconsolidated sand and gravel aquifer systems.

1.7 Geologic Setting

The Upper and Central physiographic regions of the Delaware River Basin (Basin) described in the preceding section are underlain by a much larger *geologic* basin—a depression in the earth's surface filled with layers of sedimentary rock—known as the Appalachian basin. These rock layers, or "strata," include the oil and gas-bearing rock formations known as the Marcellus and Utica Shales (see Figure 1 for the extent of these shale formations underlaying the Delaware River Basin), among others. By one account, the Appalachian basin extends across twelve states, from the Adirondack Mountains in New York to central Alabama (Colton, 1961, p.8). However, it is by no means uniform across this expanse. In contrast with areas west of the Delaware River Basin (including much of the upper Susquehanna River Basin), the upper portion of the Delaware River Basin in northeast Pennsylvania and portions of New York were subjected to recurrent mountain-building events (including rifting, subduction, subsidence, folding and faulting) over billions of years, along with recurrent glaciations, weathering, erosion, and deposition of sediments (Barnes and Sevon, 2014, pp. 8-10, 11-14, 16-18; USGS, 2018, p. 13). These continent-shaping episodes impacted the Delaware River Basin in these regions and has resulted in a landscape and a geologic setting that are distinct from areas of Pennsylvania and New York outside of the Delaware River Basin.

The tight shale formations in the Appalachian basin, portions of which are currently being used for oil and natural gas production, were once the floors of an inland sea or seas that formed during the Ordovician and Devonian Periods of the Paleozoic Era, between roughly 485-440 and 420-360 million years ago, respectively (Barnes and Sevon, 2014, pp. 11-18). These inland bodies of water (*see* Figure 6), which were relatively shallow, highly saline and poorly circulated, served as the repository for the organic matter (such as algae, spores, plants, pollen and others) and eroded sediments that would eventually coalesce to form tight, hydrocarbon-rich shales. *See,* Barnes and Sevon, 2014, pp. 11-18; Flaherty and Flaherty, 2014, pp. 3-4; GWPC and ALL Consulting, 2009, p. 14.

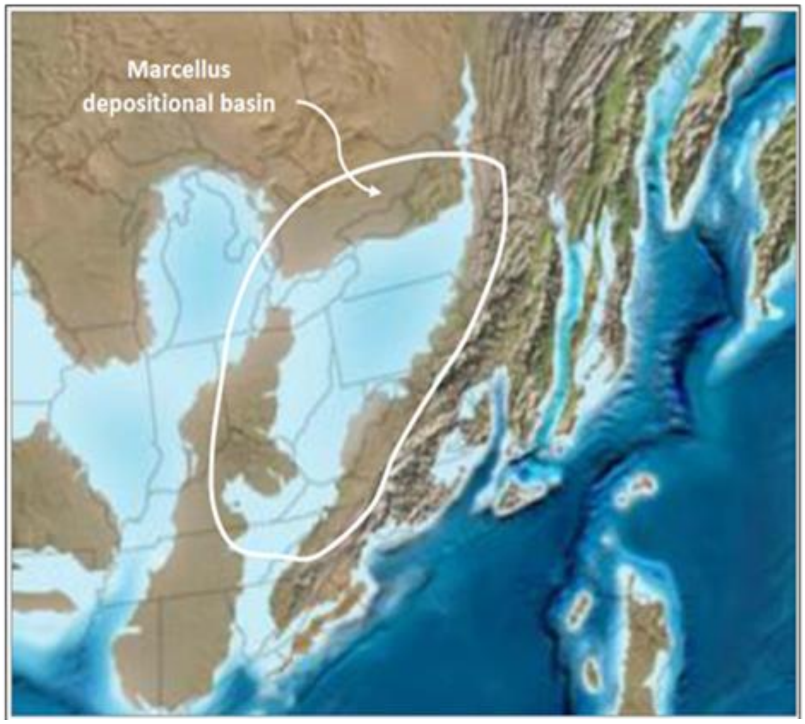

Figure 6: Conceptualization of inland sea during Paleozoic Era.
Source: EIA, 2017a, p. 7 (Figure 5)

The accumulation of oil and gas within sedimentary tight shale formations is generated by the "thermal breakdown of the organic constituents in the rocks." (USGS, 2018, p. 27). The burial of those organic-rich sediments by hundreds to thousands of feet of younger sediments that accumulate over time produces great heat and pressure that gradually breaks down the organic matter, a process known as thermal maturation. (*Id.*). The U.S. Energy Information Administration (EIA) explains the process this way:

> Heat causes the organic matter to change into the waxy material known as kerogen, then into oil, and finally into natural gas as the temperature further increases. Thermal maturity is the level of thermal alteration of rock that reflects the degree of organic matter transformation (e.g., conversion of sedimentary organic matter to petroleum or . . . natural gas).

(EIA, 2017a, p. 8).

The degree of thermal maturity “is mostly defined by burial depth.” (EIA, 2017a, p. 8). The depth to the Marcellus and Utica formations generally increases moving eastward through Pennsylvania, with some of the deepest points approaching the Delaware River Basin (*see* Figure 7). The shales in this region are buried beneath thousands to more than ten thousand feet of rock. Evidence suggests the region was previously overlain by tens of thousands of feet of additional material that has since been eroded. (Repetski *et al.,* 2008, p. 12). As a result, the shale beds within the Basin may have been subjected to greater pressure and heat over a longer period of time than much of the shale formations to the west.

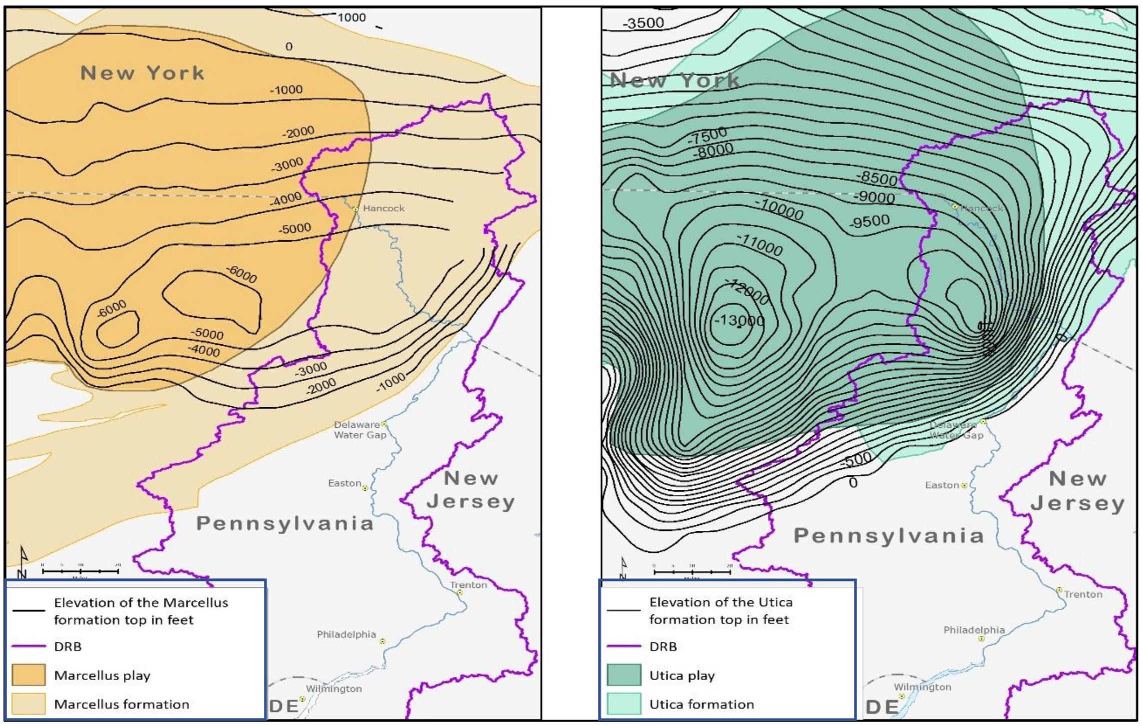

Figure 7: Marcellus and Utica Shale Formation Top Elevations.
Source: EIA, 2016a (Basin boundary added)

As shown in Figures 7 and 8, the eastern edge of the Marcellus and Utica Shale “plays” (a term used for shale formations containing accumulations of natural gas) extends into and terminates within the northwestern portion of the Delaware River Basin in Pennsylvania and New York (EIA, 2017a, p. 1 (re Marcellus); EIA, 2017b, p. 6 (re Utica)). The U.S. Geological Survey (“USGS”) notes (and as shown on Figure 7) that immediately east of the point of greatest depth of the Ordovician (Utica/Pt. Pleasant formations) and Devonian (Marcellus) shales within the Appalachian Basin:

> the rocks dip upward rapidly and some formations, including the Marcellus Shale, crop out at the Earth’s surface near the Delaware River. The deformation that generated this marked change in structural configuration produced an assemblage of Paleozoic sedimentary rocks that have been extensively folded, faulted, and eroded over geologic time . . . .

(USGS, 2018, p. 13).

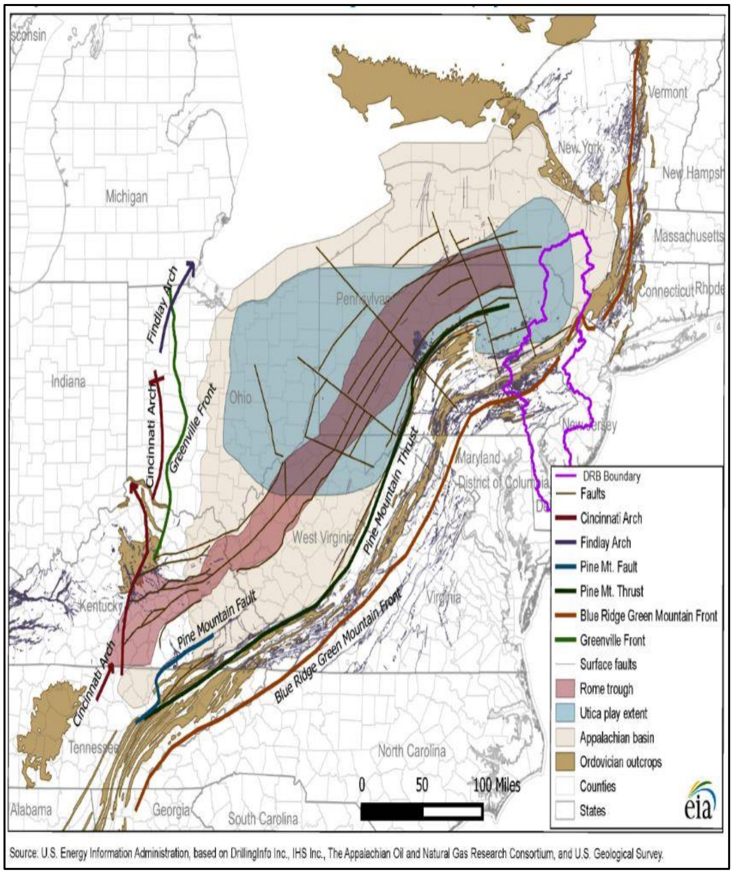

Figure 8: Major structural and tectonic features in the region of the Marcellus Shale play
Base Map Source: EIA, 2017b, p. 13 (Figure 4).

This is significant because the origin and evolution of the rocks near the Delaware River differ in many respects from those of other areas in Pennsylvania and New York. In addition, progressing eastward from the regions of the Marcellus and Utica plays where natural gas has been extracted from tight shales to date, the thermal maturity of the shales increases to values in excess of the range that is generally understood to support dry natural gas (USGS, 2018, p. 27). In theory, the extreme pressure and heat in the bedrock throughout this area may have "cooked out" the natural gas (Skrapits, 2012).

In 2018 the USGS stated that it had:

> constructed isograd maps for the Ordovician and Devonian rocks of the Appalachian [b]asin based on measured vitrinite reflectance (Ro)[9] and observed conodont color alteration (CAI)[10] values for hundreds of samples. These maps show that all of the area of northeast Pennsylvania except for the northwestern most part of Wayne County fall above the temperature of preservation of dry gas. . . . [H]owever, these observed thermal maturation levels are for *in situ* oil and gas generation/preservation, and presence of hydrocarbons that may have migrated laterally or vertically into these areas is not excluded from

[9] The Schlumberger Oil Field Glossary describes vitrinite reflectance as "A measure of the thermal maturity of organic matter. This analytical method was developed to rank the maturity of coals and is now used in other rocks to determine whether they have generated hydrocarbons or could be effective source rocks." (Schlumberger, undated).

[10] Color Alteration Index (CAI) of conodont specimens is commonly used for identifying the maximum temperature to which units of sedimentary rock, particularly carbonates, have been heated. Observable color variations in these fossils are thought to be a result of the thermally-induced structural evolution of organic carbonaceous matter (CM). Such temperature history information is extremely valuable for applications in hydrocarbon exploration as well as for constraining other temperature-related geological processes in sedimentary systems (McMillan and Golding, 2019).

these observations.[11] On the other hand, any lateral migration would have had to have been from a considerable distance, as the entire northeast corner of Pennsylvania reflects high thermal maturation levels.

(USGS, 2018, p. 27) (internal citations omitted; explanatory footnotes added).

In 2019 the USGS published a geology-based assessment of undiscovered natural gas resources in the Marcellus formation within eight states, including New York and Pennsylvania. Among the six assessment units ("AU's") the USGS defined, the estimates for natural gas recovery were lowest, by far, in the Foldbelt Marcellus Shale Gas AU, the only assessment unit applicable to the Delaware River Basin. (USGS, 2019). The EIA also has published maps that show increasing thermal maturity and shallowing as the Marcellus outcrops to the east. Figure 9 depicts the entire portion of the Marcellus

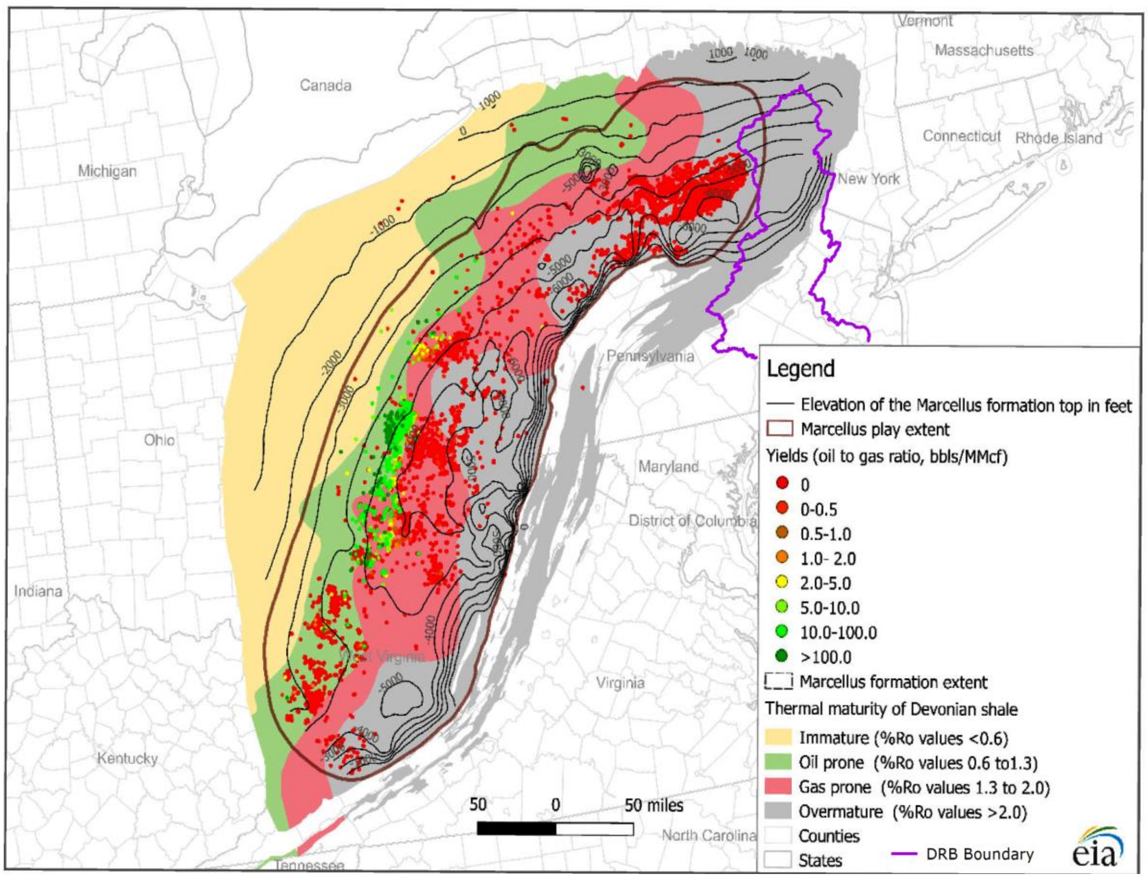

Figure 9: Marcellus Play beneath the Delaware River Basin.
Base Map Source: EIA, 2017a, p.9 (Figure 6); location of DRB boundary is approximate

[11] Heat and pressure at depth can promote natural fracturing of hydrocarbon-bearing rocks, thus allowing natural gas to migrate from an unconventional formation and be trapped elsewhere (Protero and Schwab, 1996, pp. 289-295).

Shale play beneath the Delaware River Basin as "overmature."[12] In Figure 10, the older and deeper Utica and Point Pleasant formations underlying the Delaware River Basin are likewise depicted as "overmature."

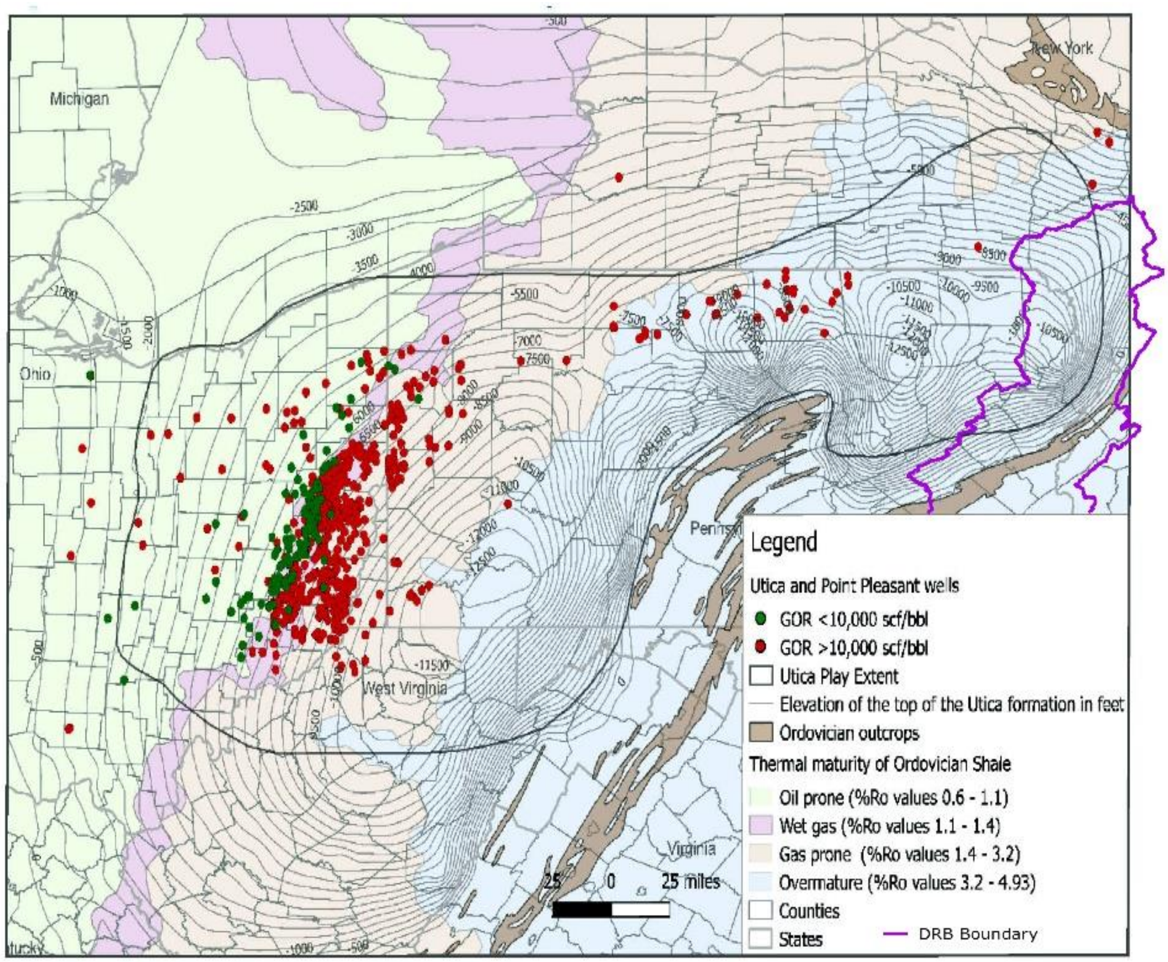

Figure 10: Utica Play beneath the Delaware River Basin
Source: EIA, 2017b, p.16 (Figure 6)

[12] According to the EIA, "Thermal maturity values (based on vitrinite reflectance, R_o measurements of core samples) in the Marcellus Shale generally increase in a southeastern direction, ranging from 0.5% R_o to more than 3.5% across the Appalachian basin." (EIA, 2017a, p. 8). EIA explains, "At thermal maturity values of greater than 3.5% R_o, the hydrocarbon production potential from the Marcellus Shale may become problematic based on the limited drilling results released to date." *Id.* In the map captioned "Initial Yields (oil to gas ratios, barrels per million cubic feet (bbls/MMcf)) of Marcellus wells as of December 2016" the EIA depicts the formation in northeastern Pennsylvania and New York State as "overmature" based on %R_o values in excess of 2.0 across this region. *Id.,* p. 9 (Figure 6) (reprinted herein as Figure 9, with Delaware River Basin boundary overlay).

1.8 Hydraulic Fracturing

The hydraulic fracturing process is accurately described in numerous industry, government and academic resources available on the Internet.[13] The description below, re-printed (but with updated annotation not in the original) from the Commission's Notice of Proposed Rulemaking in November 2017, includes a description of some of the risks and impacts to water resources associated with hydraulic fracturing.

From DRBC's Notice of Proposed Rulemaking:

> During hydraulic fracturing, hydraulic fracturing fluid consisting primarily of water and recycled wastewater mixed with chemicals is injected through a well bore into the target rock formation under pressures great enough to fracture the rock. The fracturing fluid typically includes proppants (usually sand), which hold open the newly created fractures, allowing the gas to flow back through them and up the well to the surface. After a well is "stimulated" through hydraulic fracturing, much of the injected fracturing fluid, together with brines that were trapped within the target formation, is conveyed to the surface, where these fluids are collected and managed. The returned fluids, known as "flowback" and "produced water," contain chemicals used in the fracturing mixture, as well as salts, metals, radionuclides, and hydrocarbons from the target rock formation. As discussed in greater detail below, in the Marcellus region in Pennsylvania, the median quantity of water required to stimulate a natural gas well currently averages around 17 million gallons for each fracturing event (API Exhibit 22). [As discussed in Section 2.3.2.1 of this document, a typical unconventional oil and gas well in Pennsylvania today "uses about 15-20 million gallons of hydraulic fracturing fluid to produce natural gas." (PADEP, 2018b)]. A single well may be fractured in multiple stages and/or multiple times (U.S. EPA, 2016a, p. 5-7),[14] and as many as twelve wells may be installed on a single well pad (Manda *et al.,* 2014). The volume of water and wastewater involved is thus significant.
>
> Water acquisition. The acquisition of water for use in HVHF may result in modifications to groundwater levels, surface water levels, and stream flows. The Susquehanna River Basin Commission ("SRBC") has reported that for the period 2010 through 2018 the average volume of water injected per fracturing event in natural gas wells within the Susquehanna Basin has grown from 4.3 million gallons to 12 million gallons (SRBC, 2020). During the same period, approximately 85 percent of injected water was "fresh" water from surface water and

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[13] *See e.g.,* descriptions published by: the Marcellus Shale Coalition, at: https://marcelluscoalition.org/marcellus-shale/production-processes/; the U.S. EPA, at: https://www.epa.gov/uog/process-unconventional-natural-gas-production; and Penn State University Libraries, at: https://guides.libraries.psu.edu/friendly.php?s=marcellus.

[14] Explaining that in a multi-stage hydraulic fracturing operation, specific parts of the well are isolated and hydraulically fractured until the total desired length of the well has been hydraulically fractured. *See* also, 18 C.F.R. 806.3 (SRBC regulations for review and approval of projects, defining "hydrocarbon development project" as including "all other activities and facilities associated with … the production, maintenance, operation, closure, plugging and restoration of [unconventional natural gas development] wells or drilling pad sites that require water for purposes including but not limited to, *re-stimulation and*/or re-completion of such wells …." (emphasis added).

groundwater sources, and the remaining 15 percent was recycled produced water or flowback water (SRBC, 2020). According to EPA, the median volume of water used per well fracturing event in Pennsylvania between January 2011 and February 2013 was 4.18 million gallons. EPA further reports that in at least 10 percent of cases, the water use in Pennsylvania during the same period was over 6.6 million gallons per well (U.S. EPA, 2016a, p. ES-13 (Table ES-1)). EPA has reported that in the Marcellus formation in Pennsylvania, 82 to 90 percent of the base fluid used for hydraulic fracturing is fresh water that is naturally occurring and that the remaining base fluids (10 to 18 percent) are reused and recycled produced water (U.S. EPA, 2016b, p. 43 (Table C-1)). Advances in horizontal drilling technology are leading to longer drill paths and the need for more fracturing fluid volumes for each path. According to SRBC, when the industry began lengthening its lateral well bores in 2013, the average amount of water used per fracturing event increased to approximately 5.1 to 6.5 million gallons per fracturing event (SRBC, 2016, p. 43). SRBC in 2020 reported that the average length of laterals has increased from 2,200 feet to 7,000 feet (SRBC, 2020). The associated water use per foot of well fractured also increased: early usage was in the range of 1,000 to 1,500 gallons per foot, increasing to a range of 1,500 to 1,900 gallons per foot after 2014. According to SRBC, the industry average for completion design in 2020 was about 2,200 gallons of water per linear foot (SRBC, 2020).

CONSUMPTIVE USE. In contrast with most domestic and commercial water use, most water used for HVHF is used "consumptively," meaning it is not returned to the Basin's usable ground or surface waters. According to the EPA, water accounts for 90 to 97 percent of all hydraulic fracturing fluids injected into a well for the purpose of extracting natural gas (U.S. EPA, 2016a, p. 3-21). EPA reports further that produced water, or water that flows from and through oil and gas wells to the surface as a by-product of oil and gas production over a ten-year operations period, makes up only 10 to 30 percent of the fluid injected. Accordingly, EPA estimates that 70 to 90 percent of the water used in high volume hydraulic fracturing is permanently removed from the water cycle (U.S. EPA, 2016a, p. ES-14 (Figure ES-4(a)). The SRBC's estimate is higher. SRBC (2016) reports that approximately 96 percent of water withdrawn by the natural gas industry is consumptively used in the hydraulic fracturing process and that the balance of the water is consumptively used for other activities at the drilling pads, such as well drilling, preparation of drilling muds and grout, dust control, maintenance operations, and site reclamation. In contrast, the DRBC estimates that 90 percent of water withdrawn for domestic and commercial uses in the Delaware River Basin is returned to Basin waters, either by infiltration into aquifers or by discharge to surface waters after treatment at a wastewater treatment facility. Refer to Shaffer and Runkle (2007) for comparison with climatically similar areas and the world.

CHEMICAL USE. Although chemical additives generally make up the smallest proportion of the overall composition of hydraulic fracturing fluids, they pose a comparatively high risk to ground and surface water quality relative to proppants and base fluids (U.S. EPA, 2016a, pp. ES-19-29; *see also, id.,* Text Box ES-6). Additives, which can be a single chemical or a mixture of chemicals, are combined with the base fluid to change its properties, including, for example, to adjust pH, increase fluid thickness, reduce friction, or limit bacterial growth. The EPA has identified 1,084 chemicals reported to have been added to hydraulic fracturing fluids between 2005 and 2013 (U.S. EPA, 2016a, p. ES-20; U.S. EPA, 2016b, pp. 43-47 (Sec. 1.2)). The choice of which additives to use depends on the characteristics of the targeted rock formation and operator preference, and in some cases chemical information is considered Confidential Business Information and not disclosed by the manufacturer, distributor, or fracturing operator U.S. EPA, 2016a, p. 5-20 (Text Box 5-2)). According to EPA, spills producing the most frequent or severe impacts to groundwater resources occur during the management of hydraulic fracturing fluids and chemicals (U.S. EPA, 2016a, p. ES-3). In May 2015, an EPA study compiled data on and characterized 457 hydraulic fracturing related spills that occurred between January 2006 and April 2012 in eleven states (U.S. EPA, 2015e, p. 1). The study attributed these to equipment failure, human error, failure of container integrity, and other causes, including but not limited to well communication,[15] weather, and vandalism (U.S. EPA, 2016a, p. 5-42). Storage, equipment, well or wellhead, hose or line, and "unknown" were among the identified sources of identified spills (*Id.*). Spills can affect both surface and groundwater resources, both locally and regionally, within the host state and in adjoining states. Pollution from spills and from hydraulic fracturing has occurred in parts of Pennsylvania outside the Basin where high volume hydraulic fracturing has been conducted. *See.,* e.g., Frazier, 2017a; PADEP, 2016b; U.S. EPA, 2016a; U.S EPA, 2015e; Rahm and Riha, 2014; Brantley *et al.,* 2014; PADEP, 2014c, PADEP 2016c, PADEP 2017c and PADEP 2017d; Williamsport Sun-Gazette, 2014; Considine *et al.,* 2012.

WELL DRILLING AND CONSTRUCTION. Well drilling, well construction and well stimulation associated with HVHF also carry risks for groundwater and surface water resources. These risks include turbidity or other disruptions in local ground water formations and local groundwater wells, and contamination of aquifers by fluids pumped into or flowing from rock formations penetrated by the drilling of the well, particularly in the event of a compromised well casing. Typically, the developable shale formations are vertically separated from potential freshwater aquifers by thousands of feet of sandstones and shales of moderate to low permeability. High volume hydraulic fracturing is engineered to target the prospective hydrocarbon-producing zone. Although the induced fractures create a pathway to the intended wellbore, they typically do not create a discharge mechanism or pathway beyond the fractured zone where none existed before. However, because the well bore penetrates groundwater aquifers and can be a pathway for fluid movement to existing drinking water and other groundwater resources, the mechanical integrity of the well is an important factor that affects the frequency and severity of potential water resource impacts from pollutants. A well with insufficient mechanical integrity can increase the risk of impacts and allow unintended fluid movement, including into drinking water aquifers. Such defects can arise from inadequate well design or construction or can develop over the well's lifetime, including during hydraulic fracturing. In particular, casing and cement can degrade over the life of the well because of exposure to corrosive chemicals, formation stresses, and operational stresses (e.g., pressure and temperature changes during hydraulic fracturing) (U.S. EPA, 2016a, pp. ES-28-30). Gas migration can also potentially occur as a result of poor well construction (i.e., casing and cement problems), or through

[15] "Well communication" refers to the process by which hydraulic fracturing fluids or displaced subsurface fluids move through newly created fractures into an offset well or its fracture network. *See* EPA, 2016a, p. 6-58. For further discussion, see EPA 2016a, section 6.3.2.3. *Also see,* definition of "interwellbore communication" at Response (R-35) of this Comment and Response Document.

existing abandoned wells or faults, which may be intersected inadvertently by a new oil or natural gas well. The EPA examined in detail these types of pathways for hydraulic fracturing fluids and liquids and/or gases in the subsurface to migrate into drinking water resources. *See,* U.S. EPA, 2016a, pp. ES-29-30, Figure ES-6, and pp. 6-3, 6-18, and 9-47.

WASTEWATER HANDLING AND DISPOSAL. "Produced water" (including "flowback" water) refers to any water or fluid returned to the surface through the production well as a waste product of hydraulic fracturing. This material may be stored in tanks or other containers on the pad site before it is transferred for off-site treatment and/or disposal. The composition of produced water depends on the composition of the injected hydraulic fracturing fluid and the composition of the target formation. In the Marcellus region, produced water is generated in large quantities and often contains high concentrations of total dissolved solids ("TDS" or "salts") and constituents that may be harmful to human health and the environment. Produced water from HVHF in the Marcellus has been found to contain:

- Salts, including chloride, bromide, sulfate, sodium, magnesium, and calcium;
- Metals, including barium, manganese, iron, and strontium;
- Naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes (BTEX), and oil and grease;
- Radioactive materials, including radium; and
- Hydraulic fracturing chemicals and their chemical transformation products.

(U.S. EPA, 2016b, pp. 59-81).[16]

The disposal of produced water poses a significant risk to the water resources of the Basin if the wastewater is not properly managed. The concentration of TDS in produced water can be high enough that if discharged untreated to surface water, the potential exists to adversely affect designated uses of surface water, including drinking water, aquatic life support, livestock watering, irrigation, and industrial use, and to degrade water quality in Commission-designated Special Protection Waters. *See*, WC § 3.10.2 (Uses to be protected basinwide) and *id.* § 3.10.3 A.2. ("It is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values."). Because produced water contains high TDS and dissolved inorganic constituents that most publicly owned treatment works and other municipal wastewater treatment facilities are not designed to remove, these constituents can be discharged untreated from such facilities; can disrupt treatment processes for other substances, for example by inhibiting biological treatment; can accumulate in biosolids (sewage sludge), limiting their beneficial use; and can facilitate the formation of harmful disinfection byproducts (U.S. EPA, 2016d, pp. 41845, 41847c, 41855c). Where produced water has been discharged to domestic wastewater treatment facilities in the past, elevated concentrations of chloride and bromide have been documented in

[16] Includes a comprehensive characterization of produced water that includes a significant number of data points for the Marcellus formation.

the receiving waters (Burgos *et al.,* 2017). The discharge of bromide upstream of drinking water intakes has led to the formation of carcinogenic disinfection by-products at drinking water utilities (Parker *et al.,* 2014).

The EPA since 1979 has required zero discharge of pollutants to waters of the United States from onshore oil and gas extraction wastewater. In 2016 EPA finalized a rule establishing pre-treatment standards for discharges of wastewater from onshore unconventional oil and gas extraction facilities to municipal sewage treatment plant not fracturing fluid injected into a gas well s (also known as "publicly owned treatment works" or "POTWs") (U.S. EPA, 2016d). The EPA rule will protect POTWs from disruptions in their operations that can be caused by these wastewaters. However, the rule does not extend to commercially owned treatment works that primarily treat domestic and commercial wastewater, and it does not address the discharge to POTWs of produced water that has been partially treated at centralized waste treatment facilities. Thus, significant risks associated with the treatment and discharge of produced water remain outside the scope of current federal regulations.

SITING AND LANDSCAPES. Certain water resources in the Basin have high water resource value because of their excellent water quality or their exceptional ability to perform water supply, ecological, recreational or other water-related functions. The Commission has classified certain of these waters as Special Protection Waters through provisions of its Water Code and Comprehensive Plan (*see* Water Code, § 3.10.3 A.2) The Water Code seeks to maintain or improve the condition of these water resources through regulatory requirements such as prevention of measurable change to existing water quality, evaluation of natural wastewater treatment system alternatives, conditions or limitations on wastewater treatment facilities and control of non-point sources.

Many high value water resources are associated with and dependent on their surrounding landscapes. DRBC Special Protection Waters are located in the upper portion of the Basin where forested headwater areas and riparian buffers slow the rate and volume of stormwater runoff, replenish groundwater that serves as a source of drinking water and sustains stream flow, and control the introduction of pollutants into streams. These landscape features are particularly effective at controlling non-point source pollution that may occur following precipitation events.

High volume hydraulic fracturing and the related alteration of landscapes required to support that activity pose risk to high value water resources. As noted in Figure 1, it is expected that practically all of the development and related disturbances from high volume hydraulic fracturing would occur in the drainage area of DRBC Special Protection Waters. Approximately 70 percent of the Basin area underlain by the Marcellus and Utica Shales (largely in the drainage area of Special Protection Waters) is forested. The average total disturbance associated with a single Marcellus Shale well pad in Susquehanna County, PA, including associated access roads and utility corridors, is estimated at 3.1 hectares (7.7 acres) (Slonecker *et al.,* 2013, p. 19, Table 2). Off-site facilities such as gathering lines involve additional disturbances. These landscape changes will reduce forested areas and potentially vegetated buffers, increase non-point source pollution, diminish groundwater infiltration, and risk adversely affecting water quality and quantity in surface and groundwater. Because high volume hydraulic fracturing would most likely occur in headwater areas in the drainage area to Special Protection Waters, the risks of degrading water resources and impairing the effectuation of the Comprehensive Plan are of particular concern.

The U.S. EPA's 2016 report, *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States,* uses the "hydraulic fracturing water cycle" as the organizational structure for its investigations. Similar to the above description, the stages and activities of the hydraulic fracturing water cycle as EPA defined it include:

- **Water Acquisition:** the withdrawal of groundwater or surface water to make hydraulic fracturing fluids;
- **Chemical Mixing:** the mixing of a base fluid (typically water), proppant, and additives at the well site to create hydraulic fracturing fluids;
- **Well Injection**: the injection and movement of hydraulic fracturing fluids through the oil and gas production well and in the targeted rock formation;
- **Produced Water Handling**: the on-site collection and handling of water that returns to the surface after hydraulic fracturing and the transportation of that water for disposal or reuse; and
- **Wastewater Disposal and Reuse:** the disposal and reuse of hydraulic fracturing wastewater.

(U.S. EPA, 2016a, p. ES-9)(footnote omitted)). Each of these phases or combinations of them could properly be identified by the Commission as a project or projects, and each such project could be considered separately by the Commission for purposes of evaluation. *See,* Compact, § 1.2(g).

1.9 The Delaware River Basin Compact and the Comprehensive Plan

A brief overview of the statute known as the Delaware River Basin Compact ("Compact") and a central feature of that statute—the Comprehensive Plan—are important to understanding the actions being taken by the Commission.

THE COMPACT. In 1961, the United States and the states of Delaware, New Jersey, and New York and the Commonwealth of Pennsylvania enacted concurrent legislation creating the DRBC to manage the water resources of the Basin.[17] The Compact recognized "the water and related resources of the

[17] The federal law enacting the Compact, Public Law 87-328, is set forth in 75 Stat. 688. The laws of the Basin states enacting the Compact are 53 Delaware Laws, Chapter 71; New Jersey Laws of 1961, Chapter 13, New York Laws of 1961, Chapter 148; Pennsylvania Acts of 1961, Act No. 268. The Compact, DRBC Water Quality Regulations and DRBC Rules of Practice and Procedure, cited in this document are available on the Regulations page of the DRBC website, http://www.nj.gov/drbc/about/regulations/.

Delaware River Basin as regional assets" and established the Commission as an agency through which these vital shared resources could be jointly managed. (Compact Part 1, Recitals). Water resources include surface water, groundwater and "related natural resources," as well as "related uses of land." (Compact § 1.2(i)).

The five parties to the Compact act through their respective Commissioners (or their alternates), who are referred to in the Compact as the "members" of the Commission (Compact §§ 2.2 and 2.3). The DRBC's members are, *ex officio,* the governors of the four Basin states and a representative of the President. By statute, the President's representative is the commander of the North Atlantic Division, U.S. Army Corps of Engineers. (Compact, § 2.2, as amended by Pub. L. 110-114 § 5019). Each Commissioner is entitled to one vote. (Compact, § 2.5). Decisions of the Commission are made by vote of a majority of the membership, *i.e.,* by three or more votes. (*Id.*)

Each Commissioner may appoint an alternate or alternates with authority to attend all meetings of the Commission and to vote in the member's absence. Pursuant to Section 14.5(a) of the Compact, the Commissioners appoint an Executive Director to oversee the day-to-day activities of Commission staff. However, the Compact is clear that the Commissioners, not the Executive Director, serve as the governing body of the DRBC (Compact, § 14.1(b)(1)).

Central to the Commission's mission is the adoption of a "comprehensive plan for the immediate and long range development and uses of the water resources of the Basin" to which federal, state and local agencies and private parties are bound (Compact, §§ 3.2 and 13.1). The Compact provides the Commission with a range of tools for developing and implementing its Comprehensive Plan, including powers to conduct and sponsor research (§ 3.6(c)); to plan, design and construct projects, activities and services (§ 3.6(a)); to establish rules (as described below), and to review projects sponsored by other entities, including "any person, corporation or government authority," that may have a substantial effect on the Basin's water resources, to ensure such undertakings do not substantially impair or conflict with the Comprehensive Plan (§ 3.8).

The Commission's rulemaking authority is described in several of the Compact's provisions. The Commission may "make and enforce reasonable rules and regulations for the effectuation, application and enforcement of the Compact" (§ 14.2); it may "establish standards of planning, design and operation of all projects and facilities in the Basin which affect its water resources" (§ 3.6(b)); and it may "have and exercise all powers necessary or convenient to carry out its express powers" (§ 3.6(h)). In addition, Article 5 of the Compact, which focuses specifically on pollution control, provides that the Commission may "classify the waters of the Basin and establish standards of treatment of sewage, industrial or other waste" (§ 5.2) and may "adopt and from time to time amend and repeal rules, regulations and standards to control such future pollution and abate existing pollution … as may be required to protect the public health or to preserve the waters of the Basin for uses in accordance with the comprehensive plan" (*Id.*).

THE COMPREHENSIVE PLAN. In accordance with the Compact's mandate, the Comprehensive Plan is an ever-evolving compilation of projects, policies and regulations that the Commission deems necessary for the "optimum planning, development, conservation, utilization, management and control of the water resources of the Basin to meet present and future needs." (Compact, §13.1). DRBC has established by regulation and has included in its Comprehensive Plan projects, policies and regulations relating to both water quality and water quantity.

Water Quality. An important driver for enactment of the Delaware River Basin Compact was the need for effective management of water quality in the Basin's shared waters. In important part through the Commission's efforts from 1961 through the present, dissolved oxygen in the Estuary has been restored from conditions that at times and locations were incapable of supporting aquatic life, to levels that consistently support the maintenance of fish populations and passage of fish that swim up- or downstream to spawn. However, the Estuary and Bay are still plagued by a legacy of industrial pollution, including by persistent toxic pollutants that bioaccumulate in the tissues of fish and other animals (including humans), and that have given rise to state-issued limits on the consumption of many species of fish caught in the Estuary and Bay.

With respect to surface water quality, the Commission has adopted standards that include numeric criteria—some of Basin-wide application and others for specific water quality zones—and narrative standards that include the water uses to be protected by the numeric criteria. *See* Delaware River Basin Water Code, Article III – Water Quality Standards for the Delaware River Basin. In accordance with these regulations the Commission has provided that, "[t]he quality of Basin waters, except intermittent streams, shall be maintained in a safe and satisfactory condition for" a list of uses that includes "agricultural, industrial and public water supplies after reasonable treatment . . . ; wildlife, fish and other aquatic life; . . . and recreation" among others (Water Code § 3.10.2. B.).

In the Estuary and Bay, the Commission has taken important steps to restore water quality impairments caused by legacy pollutants. It has done so most recently through the development of a total maximum daily load ("TMDL") for highly toxic polychlorinated biphenyls ("PCBs"), by allocating to major municipal and industrial point sources a maximum quantity of the pollutant they may discharge, and by the adoption of a regulation, included in the Comprehensive Plan, requiring each major discharger to reduce its loading of PCBs to Basin waters by tracking down and removing the sources of these harmful chemicals. (Water Code § 4.30.9). As effective as this process has been, the cost is high, and unrestricted human consumption of Estuary fish will not be possible for decades.

Understanding the expense—in both time and resources—of restoring waters impaired by pollution, the Commission has taken initiatives to keep the Basin's clean waters clean. Based on years of data gathering and analyses, the Commission classified the waters of the main stem Delaware River upstream of the head of tide in Trenton, New Jersey, and certain portions of tributaries to these waters as Special Protection Waters,[18] citing their "exceptionally high scenic, recreational, ecological, and/or water supply values" (Water Code § 3.10.3 A.2.). Waters so classified are subject to antidegradation requirements for both point and nonpoint sources of pollution intended to support the goal of "no measurable change … except toward natural conditions." (*Id.*).

The Commission has also adopted regulations and included in the Comprehensive Plan measures to protect groundwater resources. A comprehensive survey on the Basin led by the United States Army Corps of Engineers at the direction of Congress provided an important basis for the Commission's

[18] Special Protection Waters are defined in DRBC regulations as Basin waters of exceptionally high scenic, recreational, ecological and/or water supply values, and include all segments of the main stem Delaware River between Hancock, New York and Trenton, New Jersey and designated portions of certain tributaries (Water Code § 3.10.3A.2 and associated Tables).

first Comprehensive Plan and early amendments to it. Published as an eleven-volume report in 1961, the survey recognized that "[r]ural users and small communities will continue to rely mainly on ground-water sources at least until such time as the quality of surface waters or the distribution of centrally treated supplies of surface waters makes their use convenient and economical for the rural users." (U.S. Army Engineer District, 1961, Vol. 1, p. 87). The Corps advised that "under these conditions and with a view to assuring an equitable supply of suitable quality water to all users in the future, it is imperative that specific programs for the controlled use and conservation of the Basin's water resources and preservation of their quality be vigorously administered" (*Id.*), and that the "rigid control of the magnitude and geographic distribution of ground-water withdrawals" be among the programs instituted to ensure adequate future supplies. (*Id.,* p. 88)

The Commission responded by instituting groundwater quality standards and protections as early as 1964. That year, it amended the Comprehensive Plan by Resolution No. 64-11, providing in part that:

> No underground waters, or surface waters which are or may be the sources of replenishment thereof, shall be polluted in violation of water quality standards duly promulgated by the Commission or any of the signatory parties.

(Water Code § 2.20.5). By the same resolution, the Commission provided that:

> The underground water resources of the Basin shall be used, conserved, developed, managed, and controlled in view of the needs of present and future generations, and in view of the resources available to them. To that end, interference, impairment, penetration, or artificial recharge shall be subject to review and evaluation under the Compact.

(Water Code § 2.20.6).

During the 1970s, by Resolutions 72-14 and 78-8 the Commission defined groundwater as "all water beneath the surface of the ground" (Water Code*,* § 3.40.2) and identified the uses of these water resources to be protected as "domestic, agricultural, industrial, and public water supplies … [and] a source of surface water suitable for recreation, wildlife, fish and other aquatic life." (*Id.* § 3.40.3 A.). The groundwater quality objectives the Commission adopted to support these uses provide:

> The ground waters of the Basin shall not contain substances or properties attributable to the activities of man in concentrations or amounts sufficient to endanger or preclude the water uses to be protected.
>
> 1. Within this requirement, the ground waters shall be free from substances or properties in concentrations or combinations which are toxic or harmful to human, animal, plant, or aquatic life, or that produce color, taste, or odor of the waters.
>
> 2. Concentrations at any point shall not be degraded by the activities of man to exceed values specified by current U.S. Public Health Service Drinking Water Standards

(*Id.*, § 3.40.4 A.). The Commission further provided by regulation and amendment of the Comprehensive Plan that:

> No quality change will be considered which, in the judgment of the Commission, may be injurious to any designated present or future ground or surface water use.

(*Id.* § 3.40.4 B.);

> The processing, handling, transportation, disposal, storage, excavation or removal of any solid, liquid, or gaseous material on or beneath the ground surface of the Basin shall be conducted in such manner and with such facilities, in accordance with such regulations and requirements as the Commission may prescribe, as to prevent any of the criteria or requirements of this Section from being violated.

(*Id.* § 3.40.5 A.);

> No substances or properties which are in harmful or toxic concentrations or that produce color, taste, or odor of the water shall be permitted or induced by the activities of man to become ground water.

(*Id.,* § 3.40.5 B.1.); and

> Notwithstanding any other criteria or requirements of this Section, the Commission may establish . . . prohibitions which, in its judgment, are necessary to protect ground water quality.

(*Id.,* § 3.40.5 B.3.).

Water Quantity. The Commission's regulations and Comprehensive Plan also address water quantity. The Commission owns storage in the Beltzville and Blue Marsh reservoirs in the Lehigh and Schuylkill River drainages, respectively, in Carbon and Berks counties, Pennsylvania. The Commission directs releases of water from these storage pools to augment flow in the lower Basin during dry conditions. In accordance with Section 4.2 of the Compact:

> No signatory party shall permit any augmentation of flow to be diminished by the diversion of any water of the Basin during any period in which waters are being released from storage under the direction of the Commission for the purpose of augmenting such flow, except in cases where such diversion is duly authorized by this Compact, or by the commission pursuant thereto, or by the judgment, order or decree of a court of competent jurisdiction.

The Compact, Comprehensive Plan, and Commission regulations all recognize that water quality and quantity are inter-related. Because freshwater flowing downstream to the Delaware Estuary helps to repel or flush back salt-laced water from the Atlantic Ocean to keep it from reaching higher than optimal concentrations at industrial and public water supply intakes in and near the cities of Philadelphia and Camden, the Commission's members are particularly focused on maintaining adequate flows in the main stem Delaware River to repel salinity in the upper Estuary during periods of low flow. Accordingly, drought operating plans promulgated as rules by the Commission and included in its Comprehensive Plan govern releases by the City of New York from its three upper Basin reservoirs during periods of drought as defined by these rules. (Water Code § 2.5). (Operating plans agreed upon by the four Basin states and New York City govern releases from the City's reservoirs other times.)

Under the authority granted it by Section 3.8 of the Compact ("Referral and Review"), Section 3.3 ("Allocations, Diversions and Releases"), Section 13.1 ("Comprehensive Plan") and the Commission's regulations implementing these sections, the Commission also allocates surface and ground water for industrial, municipal and other purposes in a manner that protects water quality, aquatic life and other uses and users in the vicinity of and downstream from withdrawal points.

In addition to rules providing for water conservation, including a requirement that the owners of water supply systems serving the public conduct a detailed water audit annually (Water Code § 2.1), the Commission's rules and Comprehensive Plan include the following provisions and policies intended to ensure adequate water supplies, including in-stream flows, at all times:

> The waters of the Delaware River Basin are limited in quantity and the Basin is frequently subject to drought warnings and drought declarations due to limited water supply storage and streamflow during dry periods. Therefore, it shall be the policy of the Commission to discourage the exportation of water from the Delaware River Basin.

(*Id.*, § 2.30.2.);

> [T]he Basin waters have limited assimilative capacity and limited capacity to accept conservative substances without significant impacts. Accordingly, it also shall be the policy of the Commission to discourage the importation of wastewater into the Delaware River Basin that would significantly reduce the assimilative capacity of the receiving stream on the basis that the ability of Delaware River Basin streams to accept wastewater discharges should be reserved for users within the Basin.

(*Id.*,); and

> It is the policy of the Commission to give no credit toward meeting wastewater treatment requirements for wastewater imported into the Delaware River Basin.

(*Id.,* § 2.30.6.).

In summary, under the authorities conferred by the Compact and the obligations the Compact imposes, the Commission maintains and implements a Comprehensive Plan for the immediate and long-range development and use of the Basin's water resources. The Comprehensive Plan contains provisions that pertain to water quality and water quantity with respect to both surface water and ground water. As the sections of this document describing the Basin's water resources and the process of extracting natural gas from shales show, many elements of the Comprehensive Plan are potentially affected by the development of natural gas from shale formations underlying the Basin.

2. RESPONSE TO COMMENTS

2.1 Rule Section 440.1 - Purpose, Authority and Relationship to Other Requirements

2.1.1 Authority

Statement of Concern (SC-1)

- The prohibition of HVHF in the Basin exceeds the Commission's statutory authority. The Commission's pollution control authority under Section 5.2 of the Compact is limited to establishing treatment standards.
- The perceived risk of inadvertent spills and releases cannot support a ban of HVHF under Section 5.2.
- Consumptive use and water acquisition cannot support the prohibition on HVHF; they are addressed only through Article 10 of the Compact which authorizes the Commission to regulate withdrawals in groundwater protected areas.
- The Commission's authority over siting and landscapes is set forth in Article 6 pertaining to flood plain zoning and Article 7 pertaining to watershed management; neither of these provisions authorizes a Basin-wide prohibition.

Response (R-1)

As set forth in this Response, several sections of the Compact, read independently or in concert, authorize the Commission to prohibit HVHF in the Basin. The various activities comprising or accompanying HVHF pose significant risks to the water resources of the Basin and would impair the effectuation of the DRBC's Comprehensive Plan. *See* Sections 1.9, 2.3.2 and 2.3.3 of this Comment and Response Document. The sections of the Compact discussed below authorize the DRBC to promulgate regulations, including a prohibition of HVHF, to eliminate or minimize these risks.

Section 5.2 of the Compact authorizes the Commission to "assume jurisdiction to control future pollution and abate existing pollution in the waters of the basin, whenever it determines after investigation and public hearing upon due notice that the effectuation of the comprehensive plan so requires." The Comprehensive Plan includes numerous projects that depend on the availability of water in sufficient quantity and quality for their implementation. *See* Comprehensive Plan, Section II. The Comprehensive Plan also includes DRBC's Water Code, which contains surface water quality standards identifying water uses to be protected, establishing water quality objectives for streams in the Basin, and protecting waters classified as Special Protection Waters from measurable adverse change. The Water Code also prohibits degradation of groundwater. *See* Basin Regulations—Water Code, incorporated by reference at 40 C.F.R. Part 410.

Section 440.3(a) of the HVHF regulations codifies the Commission's determination that effectuation of the Comprehensive Plan requires the Commission to assume jurisdiction to control future pollution from HVHF by prohibiting such activity in the Basin. The Commission's determination is based in part on the extensive scientific and technical analysis undertaken by the Commission staff, assisted by staff of DRBC signatory party agencies. *See*, *e.g.*, Section 2.3.1 (Basis and Background Documents), Reference List, Section 1.2 (Public Input Purpose and Process), and Section 1.3 (Overview of Comment Submissions) of this Comment and Response Document.

As explained throughout this Comment and Response Document, the analysis by Commission staff demonstrated that the following incidents, among others, which are likely to be caused by HVHF activities if undertaken in the Basin, would pollute drinking water aquifers, groundwater and surface water, and impair the Commission's Comprehensive Plan: spills and releases of HVHF chemicals and HVHF fluids; migration of methane and wastewater through the subsurface as a result of faulty well construction and defective or degraded wellbore casings or cement; spills during surface transport of materials to and from remote well pads; releases during chemical mixing and well stimulation; and spills, releases and discharges during the storage, handling or disposal of wastewater including flowback and produced water. Staff's analysis further showed that increased concentrations of pollutants due to water withdrawals to support HVHF activities, the consumptive use of water during HVHF activities, and landscape changes caused by development of well pads, roads and other HVHF activities would exacerbate the water resource impacts from the pollution incidents described above and pose their own threats to the effectuation of the Comprehensive Plan. Based upon their review and evaluation of staff's analysis, conclusions and recommendations, and as codified in Section 440.3(a), the Commissioners determined that effectuation of the Comprehensive Plan requires the Commission to control pollution from HVHF.

Section 5.2 of the Compact sets forth the standard of control that the Commission may impose: "pollution by sewage or industrial or other waste . . . shall not injuriously affect waters of the basin as contemplated by the Comprehensive Plan." Compact, §5.2, second sentence. The Comprehensive Plan includes projects incorporated by the Commission into the Plan and provides for multiple uses of the waters of the Basin by members of the Basin community. *See* Compact, § 13.1.[19] If water were not available in sufficient quality and quantity to satisfy these projects and other uses, the Comprehensive Plan would be impaired. By contaminating surface water and groundwater, including public and private sources of drinking water, polluting surface water necessary to maintain and propagate aquatic species, or otherwise creating conditions that would impair activities of water users such as water purveyors and recreational, agricultural and industrial users dependent on high water quality,

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[19] To that end, the Comprehensive Plan includes, among other things, specific water quality standards identifying water uses and stream quality objectives to protect those uses. Among others, these standards provide: "The quality of Basin waters . . . shall be maintained in a safe and satisfactory condition for the following uses: (1) . . . public water supplies after reasonable treatment, except where natural salinity precludes such uses; (2) wildlife, fish and other aquatic life; (3) recreation; . . . (6) such other uses as may be provided by the Comprehensive Plan." DRBC Water Code § 3.10.2 B. (incorporated by reference at 18 C.F.R. Part 410). The Water Quality Standards also provide that in waters classified by the Commission as Special Protection Waters, "It is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions. *Id.*, § 3.10.3 A.2. In addition, "The quality of ground water shall be maintained in a safe and satisfactory condition, except where such uses are precluded by natural quality, for use as: 1. domestic, agricultural, industrial, and public water supplies . . ." *Id.,* § 3.40.3 A.

see Sections 2.3.2 and 2.3.3 of this Comment and Response Document, HVHF would injuriously affect the waters of the Basin as contemplated by the Comprehensive Plan.

The contention of some commenters that the Commission's authority under Section 5.2 is limited to adopting treatment standards is incorrect. Section 5.2 authorizes the Commission to adopt "rules, regulations and standards to control . . . future pollution" in addition to requiring treatment of waste. *See* Compact, § 5.2, fourth sentence. This authority must be "reasonably and liberally construed[,]" Compact, § 14.21, and encompasses regulation of pollution from sources that do not treat their wastes as well as from wastewater treatment plants. Protecting water resources, including drinking water, surface water and groundwater, from pollution generated during the various HVHF phases and activities discussed throughout this Comment and Response Document is required "to protect the public health or to preserve the waters of the basin for uses in accordance with the comprehensive plan." Compact, § 5.2, fourth sentence. *See*, *e.g.*, Sections 2.3.2 and 2.3.3 of this Comment and Response Document. The water resources to be protected include groundwater as well as surface water. *See* Compact § 1.2(i).

Other provisions of the Compact also serve as sources of the Commission's authority to adopt a regulation prohibiting HVHF. Section 14.2(a) authorizes the Commission to "[m]ake and enforce reasonable rules and regulations for the effectuation, application and enforcement of this compact." Similarly, Section 3.6(h) authorizes the Commission to "exercise all powers necessary or convenient to carry out its express powers or which may be reasonably implied therefrom." Likewise, Section 3.1 of the Compact, contained within Article 3 entitled "Powers and Duties of the Commission," provides that the Commission "shall develop and effectuate plans, policies and projects relating to the water resources of the basin," and "shall adopt and promote uniform and coordinated policies for water conservation, control, use and management in the basin." Section 3.2(b) of the Compact authorizes the Commission to adopt a water resources program based on the Comprehensive Plan, presenting the quantity and quality of water resource needs. Section 3.6(b) grants the Commission authority to establish standards of planning, design and operation of all projects and facilities in the Basin which affect its water resources. Section 7.1 of the Compact instructs the Commission to promote sound practices of watershed management in the Basin. A regulation prohibiting HVHF effectuates the pollution control provisions of the Compact, promotes a uniform and coordinated policy for managing pollution from HVHF activities, sets forth a standard of operation for HVHF projects and facilities and promotes sound practices of watershed management. As such, it is authorized by Sections 14.2(a), 3.6(h), 3.1, 3.6(b) and 7.1. Similarly, the prohibition implements a water resources program within the meaning of Section 3.2(b) by protecting the Basin's water resources from degradation and diminution due to HVHF activities.

Not only do these Compact provisions provide a mechanism to implement one of the purposes of the Compact, pollution control, they also confer authority to protect those uses of water resources that are identified in the Comprehensive Plan and require a sufficient quantity as well as quality of water. *See* Compact, §§ 3.2(a) and 13.1. Competing uses, such as HVHF which consumptively uses millions of gallons of water for each fracturing event at each natural gas well, may diminish water quantity and threaten the availability of sufficient water to meet demand for drinking water, agricultural irrigation, industrial production, ecological protection and other uses. As such, the sections of the Compact discussed above grant the Commission authority to regulate consumptive use through the HVHF prohibition. In addition, because lower stream flows elevate concentrations of pollutants in waterbodies, Section 5.2 also provides authority for limiting consumptive use.

The Commission disagrees with the view of Commenters asserting that consumptive use and water acquisition are addressed only through Article 10 of the Compact. Article 10 focuses on water withdrawals and diversions. As discussed above, management of consumptive use that would affect the quantity and quality of water available to other water users is critical to effectuation of the Comprehensive Plan, and the sections of the Compact setting forth the rulemaking provisions discussed above, which protect the Comprehensive Plan, are also applicable. In addition, Section 4.1 of the Compact which grants the Commission the power to develop, implement and effectuate plans and projects for the use of the waters of the Basin for water supply provides an additional basis for regulating consumptive use and water acquisition. As detailed in this Comment and Response Document, water supplies protected by the Comprehensive Plan, including drinking water supplies, would be diminished in quantity and quality if HVHF activities occur in the Basin. Additional Sections of the Compact likewise convey authorities dependent on adequate water supplies and may be impaired by depletion of water resources through consumptive use. *See*, *e.g.*, Section 3.5 (maintaining rights under the 1954 Supreme Court Decree), Section 4.2 (water supply), Article 7 (watershed management), Article 8 (recreation), Article 9 (hydroelectric power) and Section 13.2 (water resources program). Consideration of consumptive use for purposes of the current rulemaking is discussed in Section 2.3.2.1 (Water Use) of this Comment and Response Document.

Finally, the Compact grants the Commission various authorities over "water resources" of the Basin, a term that is defined in the Compact to include "uses of land" related to "water and related natural resources in, on, under, or above the ground." Compact, § 1.2(i). The Commission is expressly authorized to promote sound practices of watershed management in the Basin, including soil conservation and protection of fish and wildlife. Compact, Article 7. As detailed in Section 2.3.2.5 (Landscape Changes) of this Comment and Response Document, HVHF may adversely affect these important features of the watershed in which HVHF would be conducted. As HVHF activities increase, the risks to water resources are particularly acute in headwater areas and the drainage areas to waters designated as Special Protection Waters in which the Commission seeks to avoid measurable adverse changes to water quality. *See* Sections 1.1, 1.6, 1.8, 1.9 (Introduction sections), Sections 2.3.2 and 2.3.3 (Significant Risks and Significant Impacts to water resources, respectively) and Section 2.3.4.1 (Consistency with DRB Compact and Other Programs) of this Comment and Response Document. The Commission's authority to conserve and manage "water resources" including "related uses of land," in combination with other authorities cited above, supports the Commission's regulation.

In sum, Compact Sections 3.1, 3.2(a) and (b), 3.6(b) and (h), 4.1, 5.2, 7.1, 13.1 and 14.2(a) separately or together provide clear statutory authority for the Commission's prohibition of HVHF.

2.1.2 State and Federal Rules

Statement of Concern (SC-2)

Several commenters questioned the need for separate regulation of HVHF by the DRBC, arguing that state and federal regulations as well as industry best management practices adequately protect against potential adverse impacts to water resources. Examples of these comments appear below:

- Potential impacts from hydraulic fracturing have been addressed for years by ever-improving industry practices, robust state regulatory programs and federal regulations.

- The DBRC should follow the federal government's lead (recognizing the strong safety record of energy development in the U.S.) and limit unnecessary regulations, not impose new, unneeded restrictions.
- The federal Clean Water Act is adequate to control potential sources of pollution from all activities including natural gas development.

Response (R-2)

The DRBC is aware of the state and federal statutes, findings, regulatory standards, and practices governing hydraulic fracturing and unconventional well drilling nationally and in the Basin states. When the member states and the federal government enacted the Delaware River Basin Compact ("Compact") creating the DRBC in 1961, they recognized the Basin's unique hydrologic and geologic setting and the unique set of demands on its water resources. They agreed that a Basin-wide approach was required to sustainably manage the Basin's resources on behalf of the millions of water users in four states who relied or would in the future rely on these limited resources. Through the adoption of policies, regulations and projects over the ensuing decades, the Commission's five signatory parties crafted a Comprehensive Plan "for the optimum planning, development, conservation, utilization, management and control of the water resources of the Basin to meet present and future needs." (Compact, § 13.1). The Compact gave the Commission the powers required to implement its Comprehensive Plan, including among others the power to "assume jurisdiction to control future pollution and abate existing pollution in the waters of the Basin, whenever it determines that the effectuation of the comprehensive plan so requires." (Compact. § 5.2). This authority was not superseded or preempted by prior or subsequent legislation enacted by the federal government or the member states. To effectuate the Comprehensive Plan, the Commission may impose requirements that go beyond those established by the Clean Water Act or member state environmental statutes if in its view the effectuation of the Comprehensive Plan so requires.

This response to comments references dozens of studies and reports that document the risks, vulnerabilities and impacts associated with high volume hydraulic fracturing (also herein, "HVHF") notwithstanding industry best practices and federal and state requirements adopted to prevent environmental harm. Based on an extensive scientific and technical analysis, the Commission staff has concluded, and the Commissioners have determined, that if HVHF were to proceed in the Basin, spills and releases of HVHF chemicals, HVHF fluids and HVHF wastewater; leaks through defective or degraded wellbore casings; migration of methane and wastewater through the subsurface; and other incidents caused by HVHF activities would likely pollute drinking water aquifers, groundwater and surface water of the Basin and impair the Commission's Comprehensive Plan. For these reasons, the Commission has determined that effectuation of the Comprehensive Plan requires the Commission to control pollution from HVHF.

Statement of Concern (SC-3)

A commenter stated that in addition to the water supply availability authority exercised by both SRBC and DRBC, any water withdrawals associated with unconventional natural gas development and high volume hydraulic fracturing are also subject to oversight by the Pennsylvania Department of Environmental Protection (PADEP) through the submittal, review and approval of water management plans.

Response (R-3)

In accordance with Pennsylvania's 2012 Oil and Gas Act ("Act 13"), "[n]o person may withdraw or use water from water sources within [the] Commonwealth for the drilling or hydraulic fracture stimulation of any natural gas well completed in an unconventional formation … except in accordance with a water management plan approved by the [Pennsylvania Department of Environmental Protection ("PADEP")].[20] Such plan must demonstrate, among other things, that "the proposed withdrawal, when operated in accordance with the proposed … operating conditions" will protect the quantity and quality of water available to other users of the same source. The PADEP's authority pursuant to this requirement overlaps with water allocation and project review authorities exercised by the Commission under the 1961 Delaware River Basin Compact.

To avoid duplication, the PADEP's regulations provide that the water management plan requirements of Act 13 and its implementing regulations will be presumed to be met when the unconventional well driller or operator has obtained an equivalent approval from the DRBC (or from one of the other basin compact commissions to which Pennsylvania is a party). *See,* 25 Pa. Code § 78a.69(d).

Statement of Concern (SC-4)

A commenter stated that waste management is beyond the scope of the Commission's authority and rests instead with the Compact' s signatory states to regulate and authorize.

Response (R-4)

Please see the Commission's response at Section 2.1.1 (Authority).

Statement of Concern (SC-5)

Commenters stated that DRBC should coordinate the regulation of natural gas with Pennsylvania through administrative agreements rather than ban it, that Pennsylvania has a world class program to regulate and develop natural gas resources safely, and that PADEP has adequate standards for natural gas drilling which are endorsed by STRONGER.

[20] 58 Pa. C.S. § 3211(m)(1). The statutory requirements, along with procedural provisions, are repeated in PA DEP regulations at 25 Pa. Code § 78a.69.

Response (R-5)

In comments submitted on DRBC's rulemaking, the Marcellus Shale Coalition ("MSC") praises Pennsylvania's unconventional natural gas development regulatory program as "world class." In doing so, the MSC fails to acknowledge its own strenuous efforts to weaken or eliminate that program. In 2016, the MSC sued the Pennsylvania Department of Environmental Protection ("PADEP" or "Department") and the Pennsylvania Environmental Quality Board seeking relief from Chapter 78a, the Department's then new regulations implementing Pennsylvania's 2012 Oil and Gas Act ("Act 13") relating to unconventional natural gas development. The rules the MSC challenged and asked the court to invalidate were designed to protect natural and public resources including—forests, game lands, wildlife areas, national natural landmarks, state or national scenic rivers, historical and archaeological sites, threatened and endangered species, critical habitats, common areas on school properties, and playgrounds, among others; provisions requiring drillers to identify, monitor, and plug inactive wells; rules for managing the difficult-to-treat wastes resulting from Marcellus Shale drilling and extraction; and rules regarding impoundments, site restoration, spill remediation, and waste reporting. *See, Marcellus Shale Coal. v. Dep't of Envtl. Prot. of Pa.*, 646 Pa. 482, 185 A.3d 985, 2018. Act 13 was adopted and Chapter 78a promulgated only after the Marcellus Shale gas extraction boom had resulted in multiple incidents involving harm to surface and ground waters after drilling accelerated in 2008.

The MSC has challenged the need for regulations that specifically target unconventional drilling, maintaining that Pennsylvania's Act 13 is "self-implementing." *Id.* The statute sets forth critical protections but does not establish the procedures required to ensure industry's compliance with them.

The most recent evaluation of Pennsylvania's oil and gas regulatory program by a more neutral evaluator, STRONGER,[21] concludes: "the Pennsylvania program is, overall, well-managed, professional and meeting its program objectives. The review team also made recommendations for improvements in the program." Pennsylvania has adopted some but not all of the improvements recommended by STRONGER. (STRONGER, 2010).

The Commission acknowledges the findings of STRONGER and the responsible regulatory oversight by the PADEP. However, based on an extensive scientific and technical analysis, the Commission staff has concluded and the Commissioners have determined that notwithstanding industry best practices and federal and state requirements, if HVHF were to proceed in the Basin, spills and releases of HVHF chemicals, HVHF fluids and HVHF wastewater; leaks through defective or degraded wellbore casings; migration of methane and wastewater through the subsurface; and other incidents associated with HVHF activities would likely contaminate drinking water aquifers, groundwater and surface water of the Basin and impair the Commission's Comprehensive Plan. To effectuate the Comprehensive Plan for the immediate and long-range development and use of the Basin's water resources, as the

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[21] STRONGER is an acronym for "State Review of Oil and Natural Gas Environmental Regulations." On its website, strongerinc.org, STRONGER describes itself as "a multi-stakeholder 501(c)3 nonprofit organization." It notes that its "Board of Directors is comprised of equal representation from the oil and gas industry, state oil and gas environmental regulatory agencies, and the environmental public advocacy community." STRONGER's stated mission is "to enhance protection of human health and the environment by educating and providing services for the continuous improvement of state oil and gas environmental regulatory programs."

Compact requires, the Commission has determined that a prohibition on HVHF within the Basin is required.

STATEMENT OF CONCERN (SC-6)

Commenters stated that:

- The oil and gas industry have been granted numerous exemptions from key provisions of no fewer than seven major federal statutes, including the National Environmental Policy Act, Safe Drinking Water Act, Clean Water Act, Clean Air Act, Resource Conservation and Recovery Act, Comprehensive Environmental Response, Compensation, and Liability Act, and Emergency Planning and Community Right-to-Know Act.
- These multiple exemptions amount to loopholes that result, at best, in inconsistent levels and scopes of scrutiny by states and tribes. At worst, as a result of these exemptions, aspects of oil and gas extraction that pose risks to the environment and human health go unregulated.
- If the industry had not received unprecedented exemptions from the nation's most important environmental and public health laws, fracking would be illegal.

RESPONSE (R-6)

The Natural Resources Defense Council, the Delaware Riverkeeper Network, and Damascus Citizens for Sustainability, among others, have expressed concerns about the exemptions from federal environmental and community right-to-know laws that have been accorded the oil and gas industry. Commenters point out that the efficacy of federal regulatory standards lies in the certainty and consistency of their application. The absence of such uniformity, they contend, results in inconsistent environmental regulation, which creates confusion and potentially may compromise public health and safety.

Inconsistency among the laws of different jurisdictions and in the implementation of such laws is a central problem that the Basin states and the federal government attempted to address through the Delaware River Basin Compact. To overcome such inconsistency, the signatories to the Compact conferred on the Commission broad authority not only to develop but to effectuate "a comprehensive plan for the immediate and long range development and use of the water resources of the Basin" (Compact, §13.1). *See* Section 2.1.1 (Authority) of this document for a detailed discussion of the Commission's authority to regulate high volume hydraulic fracturing for the extraction of oil and gas in the Basin.

Statement of Concern (SC-7)

Commenters claimed that previously, the DRBC staff told a federal court how Pennsylvania's robust and comprehensive regulatory program eliminates, reduces, and minimizes the very same perceived risks that DRBC now claims justify a ban on HVHF.

Response (R-7)

A few commenters representing industry and landowners in Wayne County, Pennsylvania cited inconsistencies between the Commission's 2017 rule proposal and statements made by DRBC's former Deputy Executive Director, Robert Tudor in the context of a 2012 court proceeding challenging DRBC's issuance of draft regulations on natural gas development in December 2010. *See* DRBC, 2012.

In a declaration in that case, Mr. Tudor stated that "[r]egulation of shale gas development in both Pennsylvania and New York was in a fluid and dynamic mode during DRBC's rule development process." (DRBC, 2012, ¶ 11). He further stated, "The draft rule may yet undergo changes to enhance its effectiveness and administration. The regulations will never be perfect, and I fully expect these rules will continue to evolve with continued input from all stakeholders." (*Id.,* ¶ 27).

Mr. Tudor's declaration expressed his personal knowledge and experience and was "true and correct to the best of [his] knowledge." Since April of 2012, the United States Environmental Protection Agency ("EPA") published its final study on impacts of the hydraulic fracturing water cycle on drinking water resources in the United States in 2016, and the New York State Department of Environmental Protection ("NYSDEC") issued its Final Supplemental Generic Environmental Impact Statement ("FSGEIS") on the state's oil, gas and solution mining regulatory program in 2015. In addition, two states within or adjacent to the Delaware River Basin—New York and Maryland—banned HVHF, and many additional scientific studies and reports have been published documenting the impacts and potential impacts of HVHF on water resources. Mr. Tudor's declaration concerning DRBC regulations proposed in 2010 does not reflect the Commission's views on the matter today, which are informed by a large volume of research and information that was unavailable at the time.

2.2 Rule Section 440.2 - Definitions

Statement of Concern (SC-8)

Commenters suggested that DRBC should use definitions adopted and recognized by EPA, PADEP or SRBC.

Response (R-8)

The Marcellus Shale Coalition ("MSC") provided detailed comments encouraging DRBC to use several definitions supported by EPA, PADEP and SRBC.

MSC recommended that the EPA definition of "CWT wastewater" be used instead of this definition proposed in the draft DRBC rules:

> "CWT wastewater" - For purposes of this part, "CWT wastewater" means any wastewater or effluent resulting from the treatment of produced water by a CWT.

The MSC proposed that DRBC use the EPA definition at 40 C.F.R. § 437.2(d):

> "Centralized waste treatment wastewater" means any wastewater generated as a result of CWT activities. CWT wastewater sources may include, but are not limited to, liquid waste receipts, solubilization water, used oil emulsion-breaking wastewater, tanker truck/drum/roll-off box washes, equipment washes, air pollution control scrubber blowdown, laboratory-derived wastewater, on-site landfill wastewaters, and contaminated storm water.

The Commission acknowledges that the definitions are similar in concept. Given that the term is used only in Rule Section 440.5, Produced Water, which has been withdrawn, the definition of "CWT wastewater" is also being withdrawn.

The MSC proposed that DRBC consider the use of the SRBC's definition of "flowback water" instead of this following definition proposed by DRBC:

> "Flowback" – Fluids returned to the surface through an oil or gas well once hydraulic fracturing pressure is released. Flowback can also refer to the stage of well completion in which fluids are returned to the surface through the well after fracturing is performed.

The SRBC definition is:

> "Flowback" – A term used to represent the return flow of water and formation fluids recovered from the wellbore of a hydrocarbon development well (including unconventional gas wells) following the release of pressures induced as part of the hydraulic fracture stimulation of a target geologic formation. These fluids are considered flowback until the well is placed into production.

The Commission acknowledges that the definitions are similar in concept. Given that the term is used only in Rule Section 440.5, Produced Water, which has been withdrawn from this rulemaking, the definition of "Flowback" is also being withdrawn.

The MSC objected to DRBC's definition of "Person" and suggested the use of the EPA definition at 40 C.F.R. § 122.2. The DRBC has used a definition similar to the proposed definition in the past and has found it to be adequate. The proposed definition is not being revised.

> "Person" – Any natural person, corporation, partnership, association, company, trust, federal, state or local governmental unit, agency, or authority, or other entity, public or private.

The MSC objected to DRBC's definition of "pollutants" and suggested the use of the EPA definition at 40 C.F.R. § 122.2, since the EPA definition includes an exemption for the oil and gas industry. The EPA definition is as follows:

> "Pollutant" means dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011, et seq.)), heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. It does not mean: (a) Sewage from vessels; or (b) Water, gas, or other material which is injected into a well to facilitate production of oil or gas, or water derived in association with oil and gas production and disposed of in a well, if the well is used either to facilitate production or for disposal purposes is approved by authority of the State in which the well is located, and if the State determines that the injection or disposal will not result in the degradation of ground or surface water resources.

The exemption in 40 C.F.R. § 122.2 refers to materials injected into wells for oil and gas production or wastewater derived from oil and gas production injected into wells for disposal. The section proposed in the DRBC draft rule refers to produced water returned from a gas well, not fracturing fluid injected into a gas well or wastewater injected for disposal. In fact, the EPA has used the term "pollutants" in regulating and studying CWTs, oil and gas wastewater, and produced water in the following documents, including:

- Natural Gas Drilling in the Marcellus Shale – NPDES Program Frequently Asked Questions, (U.S. EPA, 2011).

- Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes, (U.S. EPA, 2018b).

- Oil and Gas Extraction Effluent Guidelines and Standards, 40 C.F.R. Part 435.

DRBC administers the Compact and was not attempting to alter the oil and gas exemption in the EPA rules applicable to administration of the Clean Water Act. However, given that the term "pollutants" was used only in Section 440.5 of the proposed rule, which is being withdrawn, the definition of "pollutants" in Section 440.2 has also been withdrawn.

The MSC objected to DRBC's proposed definition of "pollutants of concern." The proposed DRBC definition read as follows:

> "Pollutants of concern" – conservative, radioactive, toxic or other substances that are potentially present in produced water, consisting of all parameters

> listed in the EPA Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (June 2016), specifically all pollutants for produced water listed in Tables C-11, C-13, C-15, C-17, and C-19.

The MSC suggests that the definition should be revised to the following based upon the MSC's interpretation of EPA rules:

> "Pollutants of concern" – the pollutant to be potentially regulated by the effluent guideline.

The MSC further suggests:

> DRBC should recognize that industry innovation has developed to the point where typical fluids used for hydraulic fracturing overwhelmingly are composed of water and sand proppant. For these reasons the DRBC should remove all reference of "pollutants of concern" from the proposed rulemaking and remove the reference to Tables C-11, C-13, C-15, C-17 and C-19 in the proposed rulemaking, as well as any other policy in the proposed rulemaking that may be based on the 2016 US EPA TDD study.

This comment fails to consider that fluids used for hydraulic fracturing also contain chemicals that could be considered pollutants and that during fracturing, these fluids interact with brine in the target formation to create produced water containing salts, metals, radioactive material and other potential pollutants. MSC is effectively suggesting that there are no "pollutants of concern" in produced water, which is contrary to abundant scientific evidence. MSC is also suggesting that none of the 75 constituents listed in the tables referenced in the proposed DRBC definition are or should be "pollutants of concern" in the Basin. These constituents include, but are not limited to: bromide, benzene, toluene, xylene, barium, arsenic, sodium, strontium, radium 226 and radium 228. DRBC does not agree that there are no "pollutants of concern" in produced water as proposed by the MSC. However, since the definition of "pollutants of concern" was used specifically in Section 440.5 that has been withdrawn, this definition has been deleted from Section 440.2.

The MSC suggests that DRBC consider the use of the definition of "production fluids" adopted by the Susquehanna River Basin Commission ("SRBC") instead of this "produced water" definition proposed by DRBC:

> "Produced water" – the water that flows out of an oil or gas well, typically including other fluids and pollutants and other substances from the hydrocarbon-bearing strata. Produced water may contain "flowback" fluids, fracturing fluids and any chemicals injected during the stimulation process, formation water, and constituents leached from geologic formations. For purposes of §§ 401.35(b) (18) and 440.5, the term "produced water" encompasses untreated

> produced water, diluted produced water, and produced water mixed with other wastes.

The SRBC definition is:

> "Production Fluids" – A term used by the Commission to represent the return flow of water or formation fluids recovered at the wellhead after the well is placed into production. This term is synonymous with "produced water".

The DRBC definition is more comprehensive and includes greater detail than the SRBC definition; however, since the definition of produced water was used specifically in Section 440.5 that has been withdrawn, this definition was deleted in Section 440.2.

The MSC suggests that DRBC consider the use of the PADEP definition of "Industrial wastewater treatment system" instead of this "wastewater treatment facility" definition proposed by DRBC:

> Wastewater treatment facility – any facility treating and discharging wastewater.

The rules, as originally proposed were intended to cover all wastewater treatment facilities and not simply industrial waste treatment facilities. However, since the definition was used specifically in Section 440.5 that has been withdrawn, this definition was deleted from Section 440.2.

Statement of Concern (SC-9)

A commenter suggested that the definitions of "flowback" and "fracturing fluids" should be deleted.

Response (R-9)

MSC provided comments to suggest DRBC delete the definitions of "flowback" and "fracturing fluids." As noted above, the definition of "flowback" will be deleted from Section 440.2 since Section 440.5 has been withdrawn and the definition is no longer needed. The definition of "fracturing fluids" is needed to support another definition in the rules and as such, it will not be deleted.

Statement of Concern (SC-10)

Commenters suggested that the use of the term "high volume hydraulic fracturing" should be deleted or redefined.

Response (R-10)

The MSC claims that the term is rarely used and that DRBC is misleading the public by implying that it is a commonly used term in the region or the industry. MSC further contends that DRBC's notice of rulemaking suggested that it was a "common term" that the industry had seen before as part of the New York State Supplemental Generic Environmental Impact statement ("SGEIS"). The Commission acknowledges that the use of the term by New York State does not necessarily make the term "common." However, an internet search of the term "high volume hydraulic fracturing" produces several sources within and outside the northeastern United States that use the term (*See e.g.*, Wright and Muma, 2018 (Wichita, KS); Haley *et al.,* 2016 (Pittsburgh, PA; Morgantown, WV; Lubbock, TX; and Parachute, CO); Mrdjen and Lee, 2016 (Columbus, OH); Korfmacher *et al.,* 2013 (Rochester, NY; Washington, D.C.; and Roanoke, VA). MSC stated that no states in the region use the term "high volume hydraulic fracturing." To the contrary, in addition to the New York State DEC, the Pennsylvania DEP has used the term, for example, in summarizing amendments to the Commonwealth's rules governing Oil and Gas Development (Chapter 78a). (PADEP, 2016g). The Commission's Notice of Rulemaking is not misleading. Neither the Notice of Proposed Rulemaking nor the Rules are being revised to remove the term.

The MSC also objected to the 300,000 gallon threshold adopted from the NYS EIS process. Many rules have thresholds, and the threshold selected for this rule is the use of a combined total of 300,000 or more gallons of water during all stages in completion of a natural gas well. Below such threshold, the prohibition does not apply. The Commission reviewed the New York State SGEIS threshold, which is set forth below.

> 3.2.2.1 SGEIS Applicability - Definition of High Volume Hydraulic Fracturing. High volume hydraulic fracturing is done in multiple stages, typically using 300,000-600,000 gallons of water per stage. High volume hydraulic fracturing in a vertical well would be comparable to a single stage. Wells hydraulically fractured with less water are generally associated with smaller well pads and many fewer truck trips, and do not trigger the same potential water sourcing and disposal impacts as high volume hydraulically fractured wells. Therefore, for purposes of the SGEIS and application of the mitigation requirements described herein, high volume hydraulic fracturing is defined as hydraulic fracturing that uses 300,000 or more gallons of water, regardless of whether the well is vertical, directional or horizontal. Wells requiring 299,999 or fewer gallons of water to fracture low-permeability reservoirs are not considered high volume and will be reviewed and permitted pursuant to the 1992 GEIS and Findings Statement.

(NYSDEC, 2015b, p. 3-6). The Commission found the threshold as expressed by NYSDEC to be rational and appropriate for use by the DRBC. This is particularly so, given that impairments of water uses outside the Delaware River Basin have been shown to accompany the practice of hydraulic fracturing using 300,000 gallons or more of water.

The MSC objected to the phrase, "whether the water is fresh or recycled and regardless of the chemicals or other additives mixed in the water" in the definition of high volume hydraulic fracturing. The reason given by MSC was that, "The 'risks' upon which the DRBC is endeavoring to base the proposed regulations do not extend to water and sand in their natural states, and the inclusion of fresh water in this definition tries to introduce a risk of using fresh water for hydraulic fracturing that does not exist." The assertion that DRBC included "fresh water" in an attempt to introduce a risk that does not exist is inaccurate. The proposed definition recognizes that "fresh water," recycled water, or a combination of the two may be used in hydraulic fracturing. The definition attempts to clarify that the threshold applies to all water-based fluids and not merely to one or the other. As noted in many studies and as discussed further in this comment response document, there are risks to water resources associated with the use of any water-based fluids in hydraulic fracturing.

Other commenters suggested that the 300,000 gallon threshold be eliminated and that all hydraulic fracturing activities and all natural gas well development, including the development of conventional wells, be prohibited. A principal aim of these regulations is to avoid impairment of the Commission's Comprehensive Plan for Basin's water resources. For unconventional wells, for practical purposes, current hydraulic fracturing practices would include the use of more than 300,000 gallons per day of water in almost all cases. Considering that technologies change over time, the rules would not prohibit use of significantly less water and the resulting generation of significantly less wastewater and other waste. Such projects would still require review by the Commission under the Compact and existing regulations if they may have a substantial effect on the water resource of the Basin, but they would not be prohibited by the Final Regulations.

The definition of high volume hydraulic fracturing has not been deleted or revised.

Statement of Concern (SC-11)

Commenters suggested that the use of the term "pollutants of concern" should be deleted or redefined.

Other commenters suggested that the definition of "pollutants of concern" was too limiting since it is tied to a finite list of compounds on EPA's Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (June 2016), specifically all pollutants for produced water listed in Tables C-11, C-13, C-15, C-17, and C-19. They recommended the use of the term "current pollutants of concern" rather than "pollutants of concern" to acknowledge gaps in data and the need for regular updates of the EPA list.

Response (R-11)

The definition of "pollutants of concern" is used specifically in Section 440.5 which has been withdrawn. The definition of "pollutants of concern" has been deleted in Section 440.2. *See also,* response to SC-8 above.

Statement of Concern (SC-12)

Commenters suggested that the term "high volume hydraulic fracturing" should include non-water-based fluids.

Response (R-12)

Currently, practically all high volume hydraulic fracturing is performed using water-based fluids. It is recognized that other fluids and other methods may be used now and in the future to perform hydraulic fracturing. The DRBC manages the water resources of the Basin in accordance with its Comprehensive Plan. Based on its extensive scientific and technical analysis, DRBC determined that the risks, vulnerabilities and impacts of HVHF would likely impair the uses of water resources in accordance with the Commission's Comprehensive Plan. To date, DRBC has not made a similar determination for hydraulic fracturing using non-water-based fluids. Accordingly, the rules address only the prohibition of high volume hydraulic fracturing using water-based fluids only. Any undertakings that involve the use of other fluids or methods may be considered for review by the Commission pursuant to the Compact and existing regulations if they are projects having a substantial effect on the water resources of the Basin. Considering potential advances in technology, such projects would be considered on a case by case basis.

The definition of high volume hydraulic fracturing has not been revised to include non-water-based fluids.

2.3 Rule Section 440.3 – High Volume Hydraulic Fracturing

2.3.1 Basis and Background Documents

2.3.1.1 U.S. EPA Reports

In December 2016 the United States Environmental Protection Agency ("EPA") completed a multi-year comprehensive study entitled *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States* (U.S. EPA, 2016a). The Commission generally agrees with EPA's findings and conclusions and has relied in part upon the 2016 report and other reports prepared by the EPA as one of the bases for the proposed rules as noted in the notice of rulemaking. Commenters on the draft rule offered interpretations of the 2016 EPA report that differ from the Commission's and expressed both opposition and support for DRBC's reliance on EPA's study. Paraphrased comments and DRBC responses concerning the EPA report are provided in this section.

Statement of Concern (SC-13)

Many commenters suggested that the 2016 EPA study provides scientific evidence that fracking activities can impact and have impacted drinking water resources.

Many other commenters maintained that the 2016 EPA study constitutes evidence that technological advances, improved state and federal regulations, and operator compliance are sufficient to protect and preserve drinking water resources.

Some commenters alleged that DRBC has improperly relied on EPA's reference to "uncertainties [that] precluded a full characterization of the severity of impacts," while ignoring what these commenters view as fundamental: that EPA spent several years and several millions of dollars and employed hundreds of professionals in an effort that in the commenters' view failed to find evidence that hydraulic fracturing conducted on millions of wells over decades had a quantifiably severe impact on water resources.

Others suggested that the DRBC is misrepresenting the EPA study results in order to abscond with the mineral rights of Basin residents.

The Marcellus Shale Coalition ("MSC") commented that by focusing on "the mechanisms by which hydraulic fracturing *could potentially* impact water resources, [the DRBC] failed to note specific evidence contained within the [2016 EPA] report that demonstrated both the rarity of impacts and low severity of impacts that have actually occurred." (MSC, 2018, p. 9 (tech.)(emphasis in original)). The MSC pointed out that "For a sense of scale, approximately 25,000 to 35,000 wells were hydraulically fractured in the United States between 2011 and 2014" and that "[a]fter reviewing over 3,000 sources of information over six years, with multiple public engagements and outside technical reviews, the EPA was not able to determine that hydraulic fracturing had caused widespread or systemic impacts to drinking water supplies in the United States—let along [*sic*] *any* impacts to drinking water supplies. Nearly 8,000 of these wells were located in the Commonwealth of Pennsylvania, yet the DRBC failed to rely upon any of this experience to inform its seemingly foregone conclusion to prohibit so-called HVHF." *Id.* (emphasis in original).

RESPONSE (R-13)

The following excerpt from the Executive Summary of U.S. EPA (2016a, pp. ES-3-4) sets forth the report's conclusions in part:

> The hydraulic fracturing water cycle describes the use of water in hydraulic fracturing, from water withdrawals to make hydraulic fracturing fluids, through the mixing and injection of hydraulic fracturing fluids in oil and gas production wells, to the collection and disposal or reuse of produced water. These activities can impact drinking water resources under some circumstances. Impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors. The following combinations of activities and factors are more likely than others to result in more frequent or more severe impacts:
>
> - Water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources;
>
> - Spills during the management of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources;
>
> - Injection of hydraulic fracturing fluids into wells with inadequate mechanical integrity, allowing gases or liquids to move to groundwater resources;
>
> - Injection of hydraulic fracturing fluids directly into groundwater resources;
>
> - Discharge of inadequately treated hydraulic fracturing wastewater to surface water resources; and
>
> - Disposal or storage of hydraulic fracturing wastewater in unlined pits, resulting in contamination of groundwater resources.

The above conclusions are based on cases of identified impacts and other data, information, and analyses presented in the report. Cases of impacts were identified for all stages of the hydraulic fracturing water cycle. Identified impacts generally occurred near hydraulically fractured oil and gas production wells and ranged in severity, from temporary changes in water quality to contamination that made private drinking water wells unusable (U.S. EPA, 2016a, p. ES-3-4). DRBC agrees with EPA's conclusions, and elsewhere in this response to comments references multiple studies published since 2016 that reinforce these conclusions.

EPA reported data gaps and uncertainties as factors which limited comprehensive analysis of the risks and impacts to drinking water resources associated with HVHF. The EPA properly took these limitations seriously and the Commission does as well. The Executive Summary of the EPA's report includes the following statement:

> [S]ignificant data gaps and uncertainties in the available data prevented us from calculating or estimating the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle. The data gaps and uncertainties described in this report also precluded a full characterization of the severity of impacts.

(U.S. EPA, 2016a, p. ES-4).

With respect to locational uncertainties, the report states:

> In general, comprehensive information on the location of activities in the hydraulic fracturing water cycle is lacking, either because it is not collected, not publicly available, or prohibitively difficult to aggregate. This includes information on the:
>
> - Above- and belowground locations of water withdrawals for hydraulic fracturing;
> - Surface locations of hydraulically fractured oil and gas production wells, where the chemical mixing, well injection, and produced water handling stages of the hydraulic fracturing water cycle take place;
> - Belowground locations of hydraulic fracturing, including data on fracture growth; and
> - Locations of hydraulic fracturing wastewater management practices, including the disposal of treatment residuals.

(U.S. EPA, 2016a, p. ES-44).

The contentions of some commenters concerning mineral rights are addressed elsewhere in this document. *See* in particular, Section 2.6.10, Other Legal Comments.

Statement of Concern (SC-14)

Commenters noted that the EPA made no recommendations to ban hydraulic fracturing.

Response (R-14)

The purpose of U.S. EPA, 2016a was not to make policy recommendations, and it did not do so. However, the Executive Summary states, "The scientific information in this report can help inform decisions by federal, state, tribal, and local officials; industry; and communities." DRBC is using this report and numerous other sources of information to inform its decision making.

Statement of Concern (SC-15)

Commenters suggested that the June 2015 Draft EPA Assessment Report conclusion of "no systemic widespread impacts from hydraulic fracturing" was accurate. EPA should not have reversed its original position.

Response (R-15)

EPA released the draft report to its Science Advisory Board (SAB) for public comment and peer review on June 4, 2015. In a letter dated August 11, 2016, the SAB found that:

> . . . the EPA did not support quantitatively its conclusion about lack of evidence for widespread, systemic impacts of hydraulic fracturing on drinking water resources, and did not clearly describe the system(s) of interest (e.g., groundwater, surface water), the scale of impacts (i.e., local or regional), nor the definitions of "systemic" and "widespread." (U.S. EPA SAB, 2016, p. 2).

The SAB's recommendation was supported by 26 of the 30 members on the panel (U.S. EPA SAB, 2016, p. 2). In January 2017 in response to this and other comments submitted to EPA by the SAB, the agency prepared a *Response to the U.S. Environmental Protection Agency's Science Advisory Board Review of the Draft Report Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* (U.S. EPA, 2017). The agency's response to this comment, in part, was:

> Statements of major findings included in the Executive Summary and elsewhere in the final Assessment Report have been revised for clarity. We have also revised the Executive Summary and the technical chapters (Chapters 4-9) to more clearly link statements of major findings to observations and data that support those findings.
>
> In particular, the SAB expressed concerns about the sentence "We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States" and recommended that EPA clarify and provide quantitative support for this conclusion. We note that the majority of SAB reviewers, but not all, held this view. EPA scientists carefully considered the SAB's recommendation and concluded that the sentence could not be quantitatively supported given the existing data gaps and

> uncertainties. Additionally, as noted by the SAB, the sentence was interpreted by readers and members of the public in many different ways, which showed that it did not clearly communicate the findings of the draft report. As a result, this sentence was not included in the final Assessment Report.

(U.S. EPA, 2017, pp. 164-165).

Statement of Concern (SC-16)

Several commenters stated that EPA had confirmed that the overall incidence of actual impacts is low.

Response (R-16)

The EPA report did not make a representation regarding the frequency and severity of impacts on drinking water resources nationally. Rather, the Executive Summary section of U.S. EPA (2016a, p. ES-4) stated:

> The available data and information allowed us to qualitatively describe factors that affect the frequency or severity of impacts at the local level. However, significant data gaps and uncertainties in the available data prevented us from calculating or estimating the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle. The data gaps and uncertainties described in this report also precluded a full characterization of the severity of impacts.

Chapter 10 of the report, "Synthesis" contains a review of the frequency and severity of potential water resource impacts based upon localized data. These data support the conclusions set forth in the Executive Summary, which are quoted at length earlier in this response.

Statement of Concern (SC-17)

Commenters suggested that the EPA study did not include any information about industry best practices to prevent spills, did not quantify risk or provide severity information, and did not include any substantive discussion of how hydraulic fracturing is regulated by states.

Response (R-17)

U.S. EPA (2016a) did not include a detailed analysis of how hydraulic fracturing is regulated in each state. EPA limited itself to collecting data and information on the frequency and severity of the impacts to water resources, using empirical evidence from each stage of the hydraulic fracturing water cycle.

Specifically, the Executive Summary states:

> Although no attempt was made to identify or evaluate best practices, ways to reduce the frequency or severity of impacts from activities in the hydraulic

> fracturing water cycle are described in this report when they were reported in the scientific literature. Laws, regulations, and policies also exist to protect drinking water resources, but a comprehensive summary and broad evaluation of current or proposed regulations and policies was beyond the scope of this report.

(U.S. EPA, 2016a, p. ES-11).

The evidence set forth in EPA's report makes clear that notwithstanding industry best practices and updated regulations in many states, impacts to water resources may occur and have occurred at every stage of the hydraulic fracturing water cycle.

Statement of Concern (SC-18)

Commenters suggested that DRBC did not rely upon any of the Pennsylvania experiences in the EPA report to inform its seemingly foregone conclusion to prohibit HVHF.

Response (R-18)

In its consideration of how best to address HVHF within the Basin, DRBC relied in part upon the science-based data, methods and conclusions of the 2016 EPA Final Report, including all experiences in Pennsylvania detailed in that report. Case studies and data from the Marcellus Shale region of Pennsylvania are used throughout the EPA report and contribute to the conclusions noted in the report.

Statement of Concern (SC-19)

Commenters stated that the EPA study did not find any significant correlation between hydraulic fracturing and impaired water resources.

Response (R-19)

The EPA report did not evaluate the "impairment" of water resources. The focus of the study was impacts to drinking water resources. Impairment is an EPA term related to the Clean Water Act and was not a subject of the study.

Statement of Concern (SC-20)

Commenters suggested that there are reputable studies by government agencies and academic institutions other than EPA that conclude that hydraulic fracturing is not a threat to drinking water resources.

Response (R-20)

Several commenters stated that multiple studies have concluded that hydraulic fracturing is not a threat to water resources. Comments submitted by the American Petroleum Institute (API) in particular state that: "there are a host of reputable studies by government agencies and academic institutions, coupled with empirical evidence, that lead one to firmly conclude that hydraulic fracturing is not a threat to drinking water resources." (API, 2018, p. 6). API provided references to 20 studies by "government agencies and academic institutions" that they claim support this assertion. The Commission reviewed each of the studies and has provided brief statements on each in Appendix 3 of this response to comments. In summary, none of the studies was comparable in scope to that performed by the EPA. Many of the studies focused narrowly on single potential causes of contamination, such as methane migration, rather than evaluating the entire hydraulic fracturing water cycle. In some instances, the studies were not performed by government agencies or academic institutions. Some of the cited studies were either performed by or funded by industry. The Marcellus Shale Coalition ("MSC") provided a separate, less targeted, collection.

DRBC recognizes that some individual studies have shown no or varying degrees of impact, while other studies, some of which are discussed in this Response to Comments Document, have shown impact. On the basis of the totality of the evidence considered by the Commissioners and staff, DRBC has concluded that the potential for impacts on water resources in all phases of the hydraulic fracturing water cycle is substantial and is unacceptable within the Basin. In effect, the Commission has determined that if HVHF were permitted in the Basin, spills and releases of HVHF chemicals, HVHF fluids and HVHF wastewater; leaks through defective or degraded wellbore casings; migration of methane and wastewater through the subsurface; and other incidents likely to be caused by HVHF activities would be likely to pollute drinking water aquifers, groundwater and surface water and impair the Commission's Comprehensive Plan. Accordingly, the Commission has determined that effectuation of the Comprehensive Plan compels it to prohibit HVHF for the extraction of oil and gas within the Basin.

2.3.1.2 New York State Reports

Statement of Concern (SC-21)

DRBC received many comments that were either critical or supportive of the DRBC's reliance on the Final Supplemental Generic Environmental Impact Statement ("FSGEIS") on [New York's] Oil, Gas and Solution Mining Regulatory Program (NYSDEC, 2015a) and the accompanying Public Health Review of the SGEIS by the New York State Department of Health (NYSDOH) (NYSDOH, 2014) in proposing regulations to prohibit high volume hydraulic fracturing (HVHF) within the Basin. Some commenters contended that DRBC adopted the New York State studies without conducting an assessment of its own. Others pointed to alleged limitations of the SGEIS and questioned the validity of the New York studies as a basis for DRBC's action. Still others noted that the New York studies provided a sound and justifiable basis upon which to prohibit high volume hydraulic fracturing in the Basin. Comments representative of these various perspectives are set forth below.

From commenters generally opposed to the proposed rules:

- In the proposed rulemaking, the Commission relies heavily on two specific studies to make its claims of the risks and vulnerabilities associated with fracturing – the NYSGEIS and the US Environmental Protection Agency's hydraulic fracturing drinking water impacts study. However, there are a series of recent reputable studies by no fewer than seven government agencies and several academic institutions which support the conclusion that hydraulic fracturing is not a major threat to drinking water.

- The DRBC has short circuited the process to gather credible and transparent health impact information associated with fracking by relying on one politically-driven, unscientific reference – the NYSGEIS.

- We implore the Commission to fiercely consider its reliance on the conclusions of the NYSGEIS, which process did not follow the weight-of-evidence approach, as a justification to ban hydraulic fracturing due to health concerns. It was not systematic, and it did not consider all the lines of evidence.

- The 2015 New York SGEIS should not be used as a scientific study upon which to base the development of new regulations. The 2015 New York Final SGEIS methodology and its conclusions are inappropriate for use by the DRBC.

  - Overall, the process used by the New York State Department of Health did not account for how the SGEIS itself would have reduced and eliminated potential exposures. These factors would have put the data into context, recognized the limitations of the studies reviewed, which possibly would have led to a different conclusion.

  - Furthermore, regardless of the failings of NYSDOH's review, the review is dated and should not be a primary resource for the DRBC in its decision making. The DRBC either failed to review or chose to ignore sources of additional information and findings regarding the activities of the unconventional natural gas industry.

- Our findings raise serious questions about the NYSDOH review and DRBC's reliance on the review to support its current proposal.

  - The methodology used to conduct the NYSDOH public health review was flawed. The conclusions lacked reproducibility, and the process by which the Agency arrived at their conclusion was not transparent.

  - Overall, NYSDOH did not consider how the risk mitigation and management activities recommended in the SGEIS would have reduced or eliminated potential exposures.

  - New York State's conclusions and determination to prohibit HVHF relied on a precautionary approach in light of uncertainty.

FROM COMMENTERS GENERALLY SUPPORTIVE OF THE RULES:

- The NY Department of Health concluded that the overall weight of the evidence demonstrated the likelihood that adverse health outcomes and environmental impacts from fracking could not be prevented, leading to the Governor's decision to ban high volume hydraulic fracturing in the state.

- After an exhaustive environmental and public health analysis, the State of New York prohibited fracking. New York residents continue to be positively impacted by this historic decision.

Response (R-21)

In considering how to regulate HVHF within the Delaware River Basin, the Commission relied in part on the comprehensive 2016 study by the United States Environmental Protection Agency discussed at length elsewhere in this response, as well as on the New York SGEIS and DOH analyses. It did not rely exclusively on the New York studies as some commenters have alleged. However, the Commission believes the work performed by New York State represents a thorough, balanced and unbiased evaluation that the DRBC could not responsibly ignore.

The comprehensive analysis that led to New York State's ultimate determination to prohibit HVHF began when the state, like the DRBC, saw the rapid expansion of hydraulic fracturing in the Marcellus and Utica Shale formations and recognized the potential for natural gas development to spread rapidly across a large area of south-central New York before its potential impacts on public health and the environment were fully understood. In response, the NYSDEC proactively undertook an exhaustive assessment of the potential environmental impacts associated with HVHF. NYSDEC's analysis also included consideration of a range of regulatory standards and mitigation measures that might be implemented to reduce potential adverse impacts of HVHF on the environment and public health. The decision to prohibit HVHF within New York was made in part on the basis of the significant uncertainties reported in scientific and medical studies and other literature, in the interest of protecting public health, safety and the environment.

In response to the comments that DRBC received on its draft rulemaking, the NYSDEC provided the following statement, based on information in New York State's FSGEIS, concerning the process New York employed and the findings it reached in its studies:

> The public process to develop New York's SGEIS began with public scoping sessions in the autumn of 2008. Following this, engineers, geologists and other scientists and specialists in all of NYSDEC's natural resources and environmental quality programs (Oil and Gas, Water, Solid and Hazardous Waste, Radiation, Air, Fish and Wildlife, Lands and Forests, Office of General Counsel) collaborated to comprehensively analyze a vast amount of information about the proposed operations and the potential significant adverse impacts of these operations on the environment, identify mitigation measures that would prevent or minimize any significant adverse impacts, and identify criteria and conditions for future permit approvals and other regulatory action.
>
> NYSDEC received over 260,000 public comments, an unprecedented number, combined, on the 2009 Draft SGEIS (dSGEIS) and the 2011 Revised Draft SGEIS (rdSGEIS) and the associated regulatory documents which were considered before issuing its Final SGEIS (FSGEIS). NYSDEC's environmental review associated with consideration of whether to authorize high-volume hydraulic fracturing in New York State required extensive evaluation of the current and developing science underlying high-volume hydraulic fracturing's impacts and the increasingly stringent mitigation measures to protect the environment and public health. Since the public notice of the 2009 dSGEIS, and the subsequent rdSGEIS, NYSDEC gained a more detailed understanding of the potential impacts associated with high-volume hydraulic fracturing and

horizontal drilling from: (i) the extensive public comments from environmental organizations, municipalities, industry groups, medical and public health professionals, and other members of the public; (ii) its review of reports and studies of proposed operations prepared by industry groups; (iii) extensive consultations with scientists in several bureaus within the NYSDOH; (iv) the use of outside consulting firms to prepare analyses relating to socioeconomic impacts, as well as impacts on community character, including visual, noise and traffic impacts; and, (v) its review of information and data from the Pennsylvania Department of Environmental Protection (PADEP) and the Susquehanna River Basin Commission (SRBC) concerning events, regulations, enforcement and other matters associated with ongoing Marcellus Shale development in Pennsylvania.

During the public comment period, a broad range of experts from academia, industry, environmental organizations, municipalities, and the medical and public health professions commented and/or provided analyses related to high-volume hydraulic fracturing. The comments referenced an increasing number of on-going scientific studies across a wide range of professional disciplines. These studies and expert comments highlighted that significant uncertainty remained regarding the level of risk to public health and the environment that would result from permitting high-volume hydraulic fracturing in New York, and regarding the degree of effectiveness of proposed mitigation measures. In fact, the uncertainty regarding the potential significant adverse environmental and public health impacts has been growing over time.

The NYSDEC worked closely with the New York State Department of Health (NYSDOH) during preparation of the SGEIS. Due to the increasing concern regarding high-volume hydraulic fracturing's impacts on public health, NYSDEC, on September 20, 2012, requested NYSDOH to conduct a review of the SGEIS and proposed mitigation measures and advise whether they were adequate to protect public health. On December 17, 2014, NYSDOH Acting Commissioner, Howard A. Zucker, M.D., J.D. wrote to Joseph Martens, then-NYSDEC Commissioner, regarding NYSDOH's Public Health Review of the rdSGEIS. Dr. Zucker indicated that NYSDOH's Public Health Review considered, more broadly, the current state of science regarding high-volume hydraulic fracturing and public health risks. This required an evaluation of the emerging scientific information on environmental public health and community health effects. This also required an analysis of whether such information was sufficient to determine the extent of potential public health impacts of high-volume hydraulic fracturing activities in New York State and whether existing mitigation measures implemented in other states are effectively reducing the risk for adverse public health impacts.

Dr. Zucker concluded that, as with most complex human activities in modern societies, absolute scientific certainty regarding the relative contributions of positive and negative impacts of high-volume hydraulic fracturing on public health is unlikely to ever be attained. In this instance, however, the overall

> weight of the evidence from the cumulative body of information contained in the Public Health Review demonstrated that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with high-volume hydraulic fracturing, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures to reduce or prevent environmental impacts that could adversely affect public health.
>
> NYSDOH advised NYSDEC that there are several potential adverse environmental impacts that could result from high-volume hydraulic fracturing which may be associated with adverse public health outcomes. These impacts include: (1) air impacts that could affect respiratory health due to increased levels of particulate matter, diesel exhaust, and/or volatile organic chemicals; (2) climate change impacts due to methane and other volatile organic chemical releases to the atmosphere; (3) drinking water impacts from underground migration of methane and/or fracturing fluid chemicals associated with faulty well construction or seismic activity; (4) surface spills potentially resulting in soil, groundwater, and surface water contamination; (5) surface water contamination resulting from inadequate wastewater treatment; (6) earthquakes and creation of fissures induced during the hydraulic fracturing stage; and (7) community character impacts such as increased vehicle traffic, road damage, noise, odor complaints, and increased local demand for housing and medical care. As a result, NYSDOH concluded that "until the science provides sufficient information to determine the level of risk to public health from [high-volume hydraulic fracturing] to all New Yorkers and whether the risks can be adequately managed … [high-volume hydraulic fracturing] should not proceed in New York State."

(NYSDEC, 2018).

The comprehensive New York State FSGEIS, like the 2016 EPA study, reported multiple instances of damage to water resources associated with all stages of the natural gas development process, and importantly, both sources emphasized the degree of uncertainty regarding potential future effects.

U.S. EPA (2016a, p. ES-3) states:

> Cases of impacts were identified for all stages of the hydraulic fracturing water cycle. Identified impacts generally occurred near hydraulically fractured oil and gas production wells and ranged in severity, from temporary changes in water quality to contamination that made private drinking water wells unusable… However, significant data gaps and uncertainties in the available data prevented us from calculating or estimating the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water

> cycle. The data gaps and uncertainties described in this report also precluded a full characterization of the severity of impacts.

NYSDEC (2015a, pp. 1,13) asserts:

> . . . [A] broad range of experts from academia, industry, environmental organizations, municipalities, and the medical and public health professions commented and/or provided their analyses of high-volume hydraulic fracturing. The comments referenced an increasing number of ongoing scientific studies across a wide range of professional disciplines. These studies and expert comments evidence that significant uncertainty remains regarding the level of risk to public health and the environment that would result from permitting high volume hydraulic fracturing in New York, and regarding the degree of effectiveness of proposed mitigation measures. In fact, the uncertainty regarding the potential significant adverse environmental and public health impacts has been growing over time . . . Potential significant adverse impacts on water resources exist with regard to potential degradation of drinking water supplies; impacts to surface and underground water resources due to large water withdrawals for high-volume hydraulic fracturing; cumulative impacts; stormwater runoff; surface spills, leaks and pit or surface impoundment failures; groundwater impacts associated with well drilling and construction and seismic activity; [and] waste disposal . . . .

Additional detail regarding the risks, vulnerabilities and impacts to surface and ground water resources associated with HVHF can be found in the cited reports.

Some commenters have pointed to a small number of studies that they claim show that HVHF is safe and not a threat to water resources or the environment. These commenters seem to equate the lack of a discernible cause-and-effect reported in a single study's findings with a definitive determination about HVHF activities generally, a conclusion they would apply uniformly irrespective of factors such as locality, physiography/geology/hydrology, drilling technique, personnel qualifications, professional diligence, and adherence to best management practices and compliance with standards and regulations, to name a few. DRBC addresses this claim in Section 2.3.1.1 (U.S. EPA Reports (R-13) above.

The DRBC continues to monitor the growing body of research evaluating the potential impacts to public health and the environment caused by HVHF and related activities. It has reasonably relied on the comprehensive evaluations performed by New York State and the EPA in determining that if HVHF were to be permitted in the Delaware River Basin, spills and releases of HVHF chemicals, HVHF fluids and HVHF wastewater; leaks through defective or degraded wellbore casings; migration of methane and wastewater through the subsurface; and other incidents likely to be caused by HVHF activities would be likely to pollute drinking water aquifers, groundwater and surface waters of the Basin and impair the Commission's Comprehensive Plan. The Commission's policy response – the imposition of a ban on HVHF in the Basin – is the one in its view that is required for the Commission to fulfill its responsibilities under the Delaware River Basin Compact.

2.3.2 Significant Risks to Water Resources

The Commission recognizes that risks to water resources arise not only during the relatively short-term well completion stage in the process of hydraulically fracturing the target rock formation, but throughout the life cycle of a natural gas production well. The HVHF-*related* activities, including water acquisition, chemical mixing, well injection, produced water handling, and wastewater disposal and reuse comprising what EPA has called "the hydraulic fracturing water cycle" (U.S. EPA, 2016a, p.1-4), all carry such risks. The Commission's rulemaking considers the totality of the risks from HVHF-related activities, which are described in this section.

2.3.2.1 Water Use

Statement of Concern (SC-22)

Commenters stated that there is a finite amount of water on our planet, and when water is used for hydraulic fracturing, particularly in deep geologic formations, most of it is permanently removed from the hydrologic cycle and locked away in the rock formations into which it was injected. EPA and others have reported that 80-90 percent of fluid used in the hydraulic fracturing process is fresh water, and that roughly 70-90 percent of injected water is permanently lost to the water cycle. The small portion of injected water that is returned to the hydrologic cycle after hydraulic fracturing is highly polluted. The volume of fresh water required to fracture a well is said to be increasing.

Response (R-22)

The Commission concurs that the majority of water used for hydraulic fracturing is permanently removed from the hydrologic cycle. A review of current information for high volume hydraulic fracturing (HVHF) projects in the Susquehanna River Basin ("SRB") shows that 70-90 percent of fluid used to hydraulically fracture wells in the Marcellus and Utica Shales is "freshwater." The long-term average (2008-2016) in the SRB is approximately 83 percent (SRBC, 2018). SRBC's most recent reported data indicates that the annual quantity of flowback reported as reused and injected into new wells (replacing freshwater) has remained relatively steady since 2014, at 15 percent or greater (SRBC, 2020).

Based upon a review of recent data for activity in Pennsylvania, the Commission agrees that the volume of freshwater used in each hydraulic fracturing event is increasing (Kondash *et al.,* 2018; PADEP, 2018b). This observation is confirmed by industry sources. An analysis of FracFocus data from 2013-2017, performed by ALL Consulting, LLC ("ALL") at the request of the American Petroleum Institute, found an increasing trend annually for water used per fracturing event. ALL relied for its conclusion on data for both Marcellus and Utica Shale wells (ALL Consulting, 2018, Exhibit 21). See Figure 11, below.

EXHIBIT 21: AVERAGE ANNUAL TOTAL BASE WATER VOLUME BY YEAR (FRACFOCUS DATA 2013-2017)

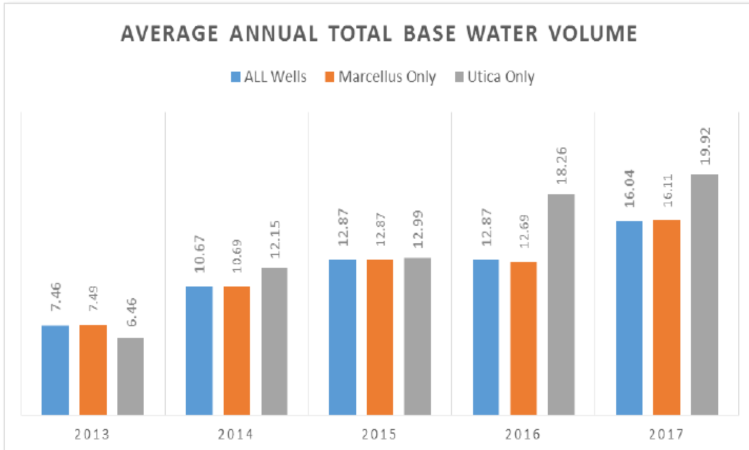

Figure 11: API Exhibit 21, Base Water Volume by Year

ALL also performed a subset analysis for the Pennsylvania counties closest to the DRB in which natural gas development is occurring—Bradford, Sullivan, Susquehanna and Wyoming (ALL Consulting, 2018, Exhibit 22). See Figure 12, below. ALL's findings included the following:

- The CY 2013 average water used per event in PA was 7.46 MG.
- The CY 2014 average water used per event in PA was 10.67 MG.
- The CY 2015 average water used per event in PA was 12.87 MG.
- The CY 2016 average water used per event in PA was 12.87 MG.
- The CY 2017 average water used per event in PA was 16.04 MG.

EXHIBIT 22: AVERAGE ANNUAL TOTAL BASE WATER VOLUME BY COUNTY (FRACFOCUS DATA 2013-2017)

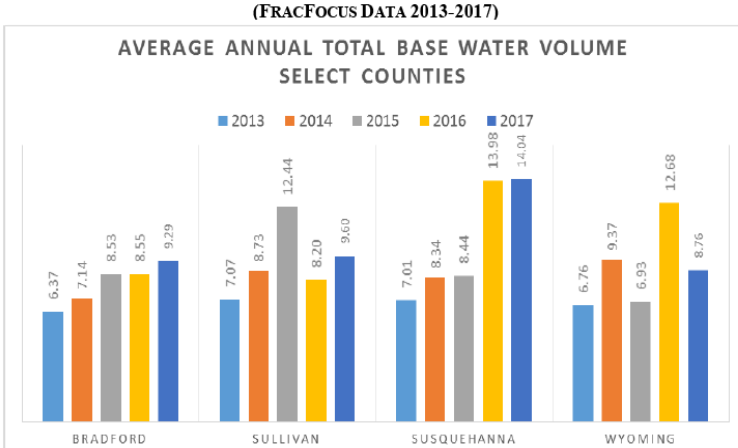

Figure 12: API Exhibit 22, Base Water Volume by County

Statement of Concern (SC-23)

Commenters stated that the Supplementary Information provided by DRBC did not compare water acquisition volumes for hydraulic fracturing to water acquisition volumes for other industries or activities currently present and active within the DRB. The potential consumptive water use requirements for natural gas development at full build-out, compared to other water uses within the Basin, are relatively minor. For example (from the commenters), nuclear power uses more than 10 times the amount of water that would be used for natural gas development; golf course maintenance uses more than 20 times the amount; and thermoelectric power generation and agriculture use more than 45 times the amount. In the Susquehanna River Basin, the average daily consumptive usage rate for the oil and gas industry is similar to the rate for manufacturing-related activities and recreational water uses, and much lower than the rate for electric power generation.

Response (R-23)

Since the proposed regulations prohibit HVHF within the Delaware River Basin, a build-out analysis of well pads, natural gas wells and corresponding water use for HVHF activities within the Basin was not conducted. As discussed in Section 2.6.6 (Economic Impacts) of this Comment and Response Document, two commenters provided estimates of the HVHF well and well pad development potential in the Basin; however, the Commission found the commenters' assumptions to be seriously flawed.

Water Use Sector	Total Annual Withdrawals (mgd)	Total Annual Consumptive Use (mgd)
Thermoelectric	3,791.7	95.7
Public Water Supply	1,003.1	100.3
Refinery	423.8	13.0
Hydroelectric	244.9	7.3
Industrial	164.4	14.4
Self Supplied Domestic Water	117.0	11.7
Agriculture	78.2	70.4
Mining	49.1	10.3
Nursery	38.4	34.5
Fish Hatchery	17.8	0.9
Golf/CC	8.3	7.4
Non-Agricultural Irrigation	5.0	4.5
2016 SRBC Natural Gas Water Use	3.9	3.7
Commercial	2.9	0.3
Prison	2.9	0.3
Ski/Snowmaking	2.4	0.5
Bottled Water	1.6	1.3
Remediation	1.3	0.1
Groundwater Remediation	1.2	0.1
Military	1.2	0.1
Parks/Recreation	1.1	0.0
School	0.8	0.1
Other	0.6	0.1
Hospital/Health	0.5	0.1
Hotel/Resort	0.1	0.0
Fire	0.0	0.0
Total	5,962.3	377.2

Table 1: Water Use by Sector - 2016

The Commission compiles water usage for approximately 26 different sectors. Table 1 shows calendar year 2016 Delaware River Basin water use data for each. Also included in Table 1 is the amount of water used for activities related to natural gas development in the Susquehanna River Basin ("SRB") during calendar year 2016 (3.9 mgd), furnished by SRBC. Water usage for natural gas development in the SRB is likely greater than the potential use for HVHF in the Delaware River Basin because of the differences between the two basins in total acreage underlain by the Marcellus and Utica Shales and due to distinct geologic characteristics.

The total water used for hydraulic fracturing and related activities in the SRB in 2016 was similar to that for each of several water use sectors in the DRB, including "Commercial," "Prisons," and "Ski/Snowmaking." The consumptive use of water for natural gas activities in the SRB is similar to that for "Non-Agricultural Irrigation" in the DRB and much lower than that for "Thermoelectric" power generation, which is the largest total water use in the DRB and among the largest consumptive uses.

One unique attribute is that the water used for high volume hydraulic fracturing activities differs from existing water uses within the Delaware River Basin in that the majority (~90 percent) of water used is completely removed from the hydrologic cycle. To our knowledge, there aren't any other similar water usage sectors which result in water almost entirely removed from the hydrologic cycle. Existing consumptive uses of water in the Delaware River Basin are still part of the hydrologic cycle. For example, thermoelectric facilities in the Delaware River Basin evaporate water that is consumptive to the DRB, but that water vapor is still a part of the hydrologic cycle and can fall as rainfall elsewhere around the world.

Although the Commission did not develop an estimate of water needs for HVHF in the Delaware River Basin, an order of magnitude estimate of water usage from HVHF activities in the SRB makes clear that larger total water uses and consumptive water uses exist in the DRB. That said, the Delaware River Basin water supply objectives and flow management operations can be impacted by consumptive uses, including high volume hydraulic fracturing, during periods of low flow and drought. Withdrawals from headwater or small order streams present challenges in terms of pass-by flow requirements, interruptible service and potential consumptive use make up. These are discussed in Section 2.3.3.2, Significant Impacts to Water Resources – Surface Waters and Aquatic Life, below. Withdrawals for consumptive use can impact downstream water availability and the management of salinity in the Delaware Estuary, where public water supply intakes for the City of Philadelphia and for a large New Jersey purveyor, among others are located. In addition, during periods of low flow and drought, withdrawals in the drainage area above the USGS gage in the Delaware River in Montague New Jersey, and not returned to that drainage area, may increase the mandatory compensating releases from the NYC Delaware River Basin reservoirs under the 1954 Supreme Court Decree and thereby diminish available public water supply storage. The Flexible Flow Management Program is discussed in Section 2.3.4.3 below.

Statement of Concern (SC-24)

Commenters note that the water usage volume per HVHF well, as estimated by DRBC in its Notice of Proposed Rulemaking, is inaccurate. Due to the lengthening of well bores, the average water usage range of 5-10 million gallons per well has increased to 10-20 million gallons per well. Commenters noted that high volume hydraulic fracturing operators in the Appalachian Basin are using significantly more water per linear foot of well than in the past due to changes in the characteristics of HVHF (horizontal bores are now curving away from the vertical well bore at shallower depths resulting in less interference with other horizontal bores), the capacity of each well is multiplying. Overall, the potential impact of water depletion to meet the increased capacity has at least doubled and the trend is for the demand to continue to increase per well drilled, making the impacts greater.

Response (R-24)

Emerging trends in water usage for HVHF confirm both that horizontal laterals appear to be increasing in length and that the average volume of water used per hydro-fracture event is increasing in both the Marcellus and Utica formations (Kondash *et al.,* 2017). The increase in water use may be attributable to the longer laterals, as well as to other operational changes.

In the SRB, from 2010 to 2018, total water use per well increased from an average of approximately 4 million gallons (mgal) to 12 mgal. SRBC reported that hydraulically fractured wells in Pennsylvania used, on average, about 3 times as much water in 2018 than they did in 2009, as the average length of laterals increased from 2,200 feet to 7,000 feet. Water use per foot of well fractured also increased: early usage was in the range of 1,000 to 1,500 gallons per foot, increasing to a range of 1,500 to 1,900 gallons per foot after 2014. Currently, an industry average for completion design is about 2,200 gallons of water per linear foot. SRBC indicates that the increase in the average consumptive use amount for hydraulic fracturing processes was evidently related to industry infrastructure build-up, technology changes, and increasing lateral lengths of new wells (SRBC, 2020).

At the request of the American Petroleum Institute, ALL Consulting LLC performed an analysis of FracFocus data from 2013-2017 and found an increasing trend in each year for water used per each “HVHF treatment” in Pennsylvania. ALL relied for this conclusion on data for both Marcellus and Utica Shale wells. ALL’s findings included the following:

- The CY 2013 average water used per event in PA was 7.46 MG.
- The CY 2014 average water used per event in PA was 10.67 MG.
- The CY 2015 average water used per event in PA was 12.87 MG.
- The CY 2016 average water used per event in PA was 12.87 MG.
- The CY 2017 average water used per event in PA was 16.04 MG.

The ALL analysis found that for CY2017, the average volume of water used to hydraulically fracture a Pennsylvania well in the Marcellus formation was 16.11 MG per event and in the Utica Formation was 19.92 MG per event. The Pennsylvania Department of Environmental Protection’s 2018 Oil and Gas Annual Report states that a typical unconventional gas well uses about 15 - 20 million gallons of hydraulic fracturing fluid to produce natural gas (PADEP, 2018b).

Statement of Concern (SC-25)

Commenters stated that EPA found that water withdrawals for hydraulic fracturing generally accounted for less than 1 percent of total water use at the county level. The experience in Pennsylvania shows that in many cases nearly 90 percent or more of flowback and produced water recovered from HVHF shale gas development is recycled and reused in subsequent wells.

Response (R-25)

Although a large portion of flowback or produced water may be recycled and reused, flowback or produced water is a small percentage of the total amount of water that is injected into the borehole during HVHF.

According to the EPA, freshwater accounts for 90 to 97 percent of all hydraulic fracturing fluids injected into a well for the purpose of extracting natural gas (U.S. EPA, 2016a, p. 3-21). EPA reports further that produced water, or water that flows from and through oil and gas wells to the surface as a by-product of oil and gas production over a ten-year operations period, makes up only 10 to 30 percent of the fluid that was originally injected. Accordingly, EPA estimates that 70 to 90 percent of the water used in high volume hydraulic fracturing is permanently removed from the water cycle (U.S. EPA, 2016a, E.S. p.12, Fig ES-4(a)). The SRBC's estimate is higher. SRBC reports that approximately 96 percent of water withdrawn by the natural gas industry is consumptively used in the hydraulic fracturing process and that the balance of the water is consumptively used for other activities at the drilling pads, such as well drilling, preparation of drilling muds and grout, dust control, maintenance operations, and site reclamation (SRBC, 2016, p. 38). While much of the recovered produced water is "recycled," the only intended use for such recycled water is additional high volume hydraulic fracturing. In other words, the recycled water is not returned to the water cycle for water resource needs and uses protected in the Comprehensive Plan, including: drinking water; agricultural; industrial; public water supplies after reasonable treatment (except where natural salinity precludes such uses); wildlife, fish and other aquatic life; recreation; navigation; and waste assimilation.

Statement of Concern (SC-26)

Commenters suggested that the cumulative impact of the buildout for natural gas development would lead to a depletion of an additional 583 billion gallons of fresh water from the Delaware River Basin systems by 2045, based on industry projections and current rates of consumption. Accordingly, a cumulative impact assessment is essential to developing a full understanding of the impacts of water withdrawals and wastewater treatment for the Delaware Basin as a whole. Commenters also questioned if the DRBC considered the effect of non-oil and gas activities on the balance between demand/availability of water resources—including activities that use comparatively larger amounts of water?

Response (R-26)

Since the proposed regulations prohibit HVHF within the Delaware River Basin, a build-out analysis of well pads, natural gas wells and an accompanying estimate of total potential water use for HVHF activities within the Basin was not performed.

Statement of Concern (SC-27)

A commenter stated that DRBC's attempt to equate longer laterals for horizontal wells with greater water demands to complete the well, implies that it's a bad thing. Instead, it is a positive technological advance because longer laterals equal less water needed to complete the wells. It's irrelevant as long as the withdrawal is properly regulated, managed and performed to avoid impacts to the water source.

Response (R-27)

The volume of freshwater used in each hydraulic fracturing event is increasing. At the request of the American Petroleum Institute, ALL Consulting, LLC performed an analysis of FracFocus data from 2013-2017 and found an increasing trend in each year for water used per each "HVHF treatment" in Pennsylvania. ALL relied for this conclusion on data for both Marcellus and Utica Shale wells (*see* Exhibit 21, reprinted above). ALL also performed a subset analysis of the four Pennsylvania counties closest to the DRB in which natural gas development is occurring—Bradford, Sullivan, Susquehanna and Wyoming (*see* Exhibit 22, reprinted above). ALL's findings included the following:

- The CY 2013 average water used per event in PA was 7.46 MG.
- The CY 2014 average water used per event in PA was 10.67 MG.
- The CY 2015 average water used per event in PA was 12.87 MG.
- The CY 2016 average water used per event in PA was 12.87 MG.
- The CY 2017 average water used per event in PA was 16.04 MG.

According to the ALL study, the increase in base fluid volume is likely a result of longer lateral well-bore lengths, greater depths drilled, optimization of multistage fractures, and the use of new fracture methods.

Water use per "HVHF treatment" is increasing. Almost all water used for HVHF is consumptively used and not returned to the hydrologic cycle. While longer laterals are undoubtedly a "technological advance" for the oil and gas industry and improve the efficiency of fracturing fluids, the permanent loss of greater volumes of water from the Basin through consumptive uses would serve to exacerbate the considerable water resource management challenges the Basin currently confronts.

Commission staff concur that water withdrawals, water uses, and consumptive uses need to be properly regulated, managed and operated in order to avoid adverse impacts to water resources and potential impairments of the water uses designated in the Commission's Comprehensive Plan.

Statement of Concern (SC-28)

A commenter stated that allowing water to be exported from the Basin for hydraulic fracturing is precedent setting. There have been no other permitted exports of water for industrial use (except as permitted by DRBC for food and beverage processing).

Response (R-28)

The majority of current exports of water from the Delaware River Basin have been approved by the Commission primarily for use as public water supplies. Exports to New York City and New Jersey under the 1954 Supreme Court Decree are also primarily for public water supply. It is noted that industrial water users are among the customers served by public water supply systems. After carefully considering the public comments received on the draft rules, the Commission is withdrawing from consideration the draft rule provision relating to the exportation of water from the Delaware River Basin for hydraulic fracturing and related activities (Section 440.4). The topic of water exportation will be addressed through one or more separate Commission actions.

Statement of Concern (SC-29)

A commenter indicated that water withdrawals from small forested streams can be carefully planned to minimize possible ecological consequences. Water-use plans can be designed to allow operators to continuously withdraw water from a stream in a small quantity that has minimal impact on stream flows, such as a quantity that cumulatively would not exceed about 10 percent of Q7-10* low flows (called an uninterrupted withdrawal). Operators could also choose to withdraw larger amounts during times of high flow.

Response (R-29)

The Commission generally concurs with this comment in that water withdrawal approvals can be structured so that potential risks to water resources can be minimized through restrictions such as pass-by flow requirements, interruptible service and consumptive use make up. The Commission's existing water withdrawal approvals generally contain conditions related to drought and pass-by restrictions due to low stream flows, etc. Potential impacts of HVHF-related withdrawals to surface water resources are discussed in greater detail in Section 2.3.3.2 (Significant Impacts to Water Resources – Surface Waters and Aquatic Life) of this Comment and Response Document.

Statement of Concern (SC-30)

A commenter suggested that all water withdrawals for current industrial uses are for processes and activities that occur within the DRB.

Response (R-30)

To date, the Commission has not approved any exportations of water solely for industrial uses. The Commission has approved several exportations of water for public water supply systems that straddle the Basin divide, which likely have some industrial use customers. The Commission is also aware that bottled water withdrawers located within the Basin export their product outside of the Basin. Exports to New York City and New Jersey under the 1954 Supreme Court Decree are primarily for public water supply purposes that include industrial uses.

Statement of Concern (SC-31)

Commenters stated that consumptive withdrawals with low bypass requirements will adversely affect downstream conditions, especially during periods of low flow, requiring increased compensating releases by New York City to meet the Montague flow objective. If water is withdrawn from the West Branch of the Delaware or the Upper Delaware, there is no way to account for the loss of water and no requirement for NYC to make up the flows.

Response (R-31)

After carefully considering the public comments received on the draft rules, the Commission is withdrawing from consideration the provisions of such rule relating to the exportation of water from the Delaware River Basin for hydraulic fracturing and related activities (Section 440.4). The topic of water exportation will be addressed through one or more separate Commission actions.

Water Use Summary

After carefully considering the comments the Commission received on the impacts of water use in the Delaware River Basin associated with high volume hydraulic fracturing, the Commission has reached the following findings and conclusions:

- The amount of water used for each hydraulic fracturing event is increasing in both the Marcellus and Utica Shale formations in Pennsylvania.
- The current water usage is estimated at 16.11 MG and 19.92 MG for each event in the Marcellus and Utica Shale formations, respectively.
- The Commission expects the increasing trend in water usage to continue.
- The water usage for high volume hydraulic fracturing activities differs from existing water usage within the Delaware River Basin in that the majority (~90 percent) of water used is completely removed from the hydrologic cycle. Most of the water currently used in the DRB is non-consumptive, which means it is returned to Basin waters and available for downstream users. Consumptive water use within the Delaware River Basin currently consists primarily of evaporative loss, which means the consumptively used water will later fall as precipitation and be available for use somewhere, if not within the Basin. The Commission is not aware of any other water use sector which completely removes water from the hydrologic cycle.

The Delaware River Basin water supply objectives and flow management operations can be significantly impacted by consumptive uses, including that associated with high volume hydraulic fracturing, during periods of low flow and drought. Withdrawals for consumptive use may impact downstream water availability and the management of salinity in the Delaware Estuary, where public water supply intakes for the City of Philadelphia and a large New Jersey purveyor, among others are located, and may impact mandatory compensating releases from NYC Delaware River Basin reservoirs.

Risks to water resources associated with the acquisition of water from the environment are primarily related to the location, timing and size of the withdrawal. In the absence of constraints on the timing and location of large withdrawals, adverse impacts at the local scale, including diminished capacity to assimilate contaminants, are a concern, particularly during seasonal low-flow periods. These items are discussed in greater detail in Section 2.3.3.2, Significant Impacts to Water Resources – Surface Waters and Aquatic Life.

On the basis of data for HVHF within the Susquehanna River Basin, the total water used for hydraulic fracturing activities is not large compared to water use by other sectors in the Delaware River Basin. However, consumptive use of such large quantities of water and permanent removal of the water from the hydrologic cycle is unique to this industry.

Although the likelihood of impacts due to water use associated with HVHF if permitted is relatively high, the severity of the impacts relative to other potential impacts described in this document is relatively low, provided that adequate regulations and best practices are employed. If the potential adverse effects of HVHF-related water use were the only water resources impact associated with HVHF, it would be possible to manage this activity effectively through regulation. However, in light of the other effects discussed in this document, the impacts associated with water use contribute to the totality of the risks and impacts that accompany HVHF and related activities. The potential for adverse impacts to water resources associated with water withdrawals for HVHF, combined with the totality of the risks, vulnerabilities, impacts, and uncertainties discussed throughout this comment and response document, supports the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.2.2 Pollution from Spills

Statement of Concern (SC-32)

Numerous comments were submitted related to the potential impacts from HVHF-related spills on the quality of water resources of the Delaware River Basin, including, among other things, harm to drinking water sources (both surface and ground) and adverse impacts to surface waters in the drainage area to waters designated by the Commission as Special Protection Waters.

This topic was addressed by numerous commenters, including but not limited to, national and regional representatives of the oil and gas industry (American Petroleum Institute, Marcellus Shale Coalition), local industry advocates (Natural Gas Now/Thomas Shepstone), and national, regional and local environmental advocacy groups (Damascus Citizens for Sustainability; Delaware Riverkeeper Network; Grassroots Environmental Education; Natural Resources Defense Council; New Jersey Sierra Club; Pennsylvania Forest Coalition), and private citizens.

The following paraphrased statements are representative of those expressing opposition to draft Section 440.3 of the rule, which would prohibit high volume hydraulic fracturing within the basin:

- The American Petroleum Institute (API) asserted that the percentage of spills/releases compared to the number of active well sites is relatively small, and predicted:
  - Based on an extrapolation of limited spill/release occurrence data (2013-2017) for Susquehanna County, PA, assuming 40 wells are drilled annually in the Delaware River Basin, only 3.63 release events would occur each year.
  - Any one of such releases would have less than a 0.5 percent chance of reaching "waters of the Commonwealth."
- According to the Marcellus Shale Coalition ("MSC"), Mr. Shepstone and some others, the sole aspect of natural gas development that the DRBC can claim to justify a fracking ban is the risk of accidents and spills, due to, among other things, equipment failure, human error, weather and vandalism. These commenters protest that the Commission has not quantified the actual risk compared to other activities conducted in the Basin.
- API stated that hydraulic fracturing operators have developed and implemented zero-discharge and controlled-collection well pad containments for use in sensitive environments to minimize the chances and consequence of hydraulic fracturing-generated wastes.
- Noting that spills of chemicals associated with hydraulic fracturing have occurred in some states, including Pennsylvania, the MSC flagged that the EPA's 2016 report stated with reference to studies of spills in Pennsylvania (i.e., Brantley *et al.,* 2014 and Considine *et al.,* 2012), that fewer than ten spills of hydraulic fracturing additives greater than 400 gallons reached surface water during the periods examined. The commenter added that:
  - In its own assessment of 151 spills in 11 states, EPA found that only 9 percent impacted surface water and 64 percent impacted soil. None of the 151 spills were reported to have impacted groundwater.
- Halliburton Energy Services, Inc. (HESI) commented that the risk profile for HVHF operations is no different than the risk profile for other industries that routinely operate within the Basin, including chemical and pharmaceutical manufacturing, wastewater treatment plants, and power plants. HESI added that:
  - When citing the EPA's conclusion on potential impacts from the chemical mixing stage of the hydraulic fracturing water cycle, the DRBC emphasized the potential for impacts but failed to present any empirical evidence.
  - States with robust regulation and reporting requirements, such as Pennsylvania, will record a greater number of spills, even though the vast majority of those spills never enter the natural environment, let alone drinking water resources.

- The DRBC Background Document inappropriately states that chemical additives "pose a comparatively high risk to ground and surface water quality relative to proppants and base fluids."
- To maintain a high level of transparency with communities, companies report specific information about fracking fluid used at each individual well via a voluntary, publicly accessible website: FracFocus.org.

Commenters who supported Section 440.3 of the draft rule, which would prohibit high volume hydraulic fracturing within the basin, offered comments along the lines of those paraphrased below:

- Liquid wastes from oil and gas drilling, if permitted into the Delaware Basin, whether treated at a CWT or not, will be spilled, dumped illegally, or released as the result of accidents.
- A Duke University study (Patterson *et al.,* 2017) shows that in Pennsylvania alone, there were 1,293 spills of fracking wastewater in a ten-year period – about 130 spills each year between 2005 and 2014.
- There is ample evidence concerning the radioactivity of these shales. The DRBC should be aware that the Marcellus Shale is highly radioactive, and other states have had difficulty measuring and controlling these radioactive components.
- Fracking wastewaters are complex and variable, fraught with uncertainties about their composition, and inherently distinct from other types of wastewater for which DRBC now issues dockets.
- The potential for contamination of ground and surface water from spills at a hydraulic fracturing well site is substantial and presents a significant threat. Studies show that spills and leaks are among the most likely means of contamination from gas and oil well extraction activities. Examination of data from four states, including Pennsylvania, found the occurrence of one spill per every 3.2 wells.
- Due to the toxic nature and sheer volumes of HVHF wastes and produced water being generated, more than a thousand truck trips per well site may be required to remove this contaminated material. Thus, there are over a thousand opportunities for an accident or spill to occur, which poses a real and potentially devastating threat to the environment.
- Spills, leaks and accidental discharges are inevitable, as evidenced here in Pennsylvania in Potter, Bradford and Tioga Counties.
- The generation, storage and transport of HVHF wastewater is already a huge issue for this country and the burgeoning volumes will only become a bigger environmental issue over time.

RESPONSE (R-32)

SYNTHESIS. The comments submitted to the DRBC are representative of those made by both industry and environmental advocates in debate over this issue nationally. Proponents of HVHF maintain that the risks to water resources from spills associated with HVHF are negligible, or at least no worse than the risks associated with other industrial activities. Commenters opposed to allowing HVHF in the Basin point to documented instances of water resource contamination caused by HVHF-related activities, including degradation of surface and groundwater caused by spills. In addition to providing scientific evidence of impacts, scientists, including EPA study authors, point to the insufficiency of available data to systematically assess the risk posed by spills and other HVHF-related incidents. After an in-depth review of the literature and available data, and after considering the voluminous materials submitted by commenters, the Commission has determined that, due to the totality of the risks to Basin waters posed by HVHF-related spills and other HVHF-related activities, prohibiting HVHF in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect public health, and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. The potential for contamination of water resources from spills is an important factor underlying the Commission's decision.

That spills associated with HVHF-related activities have adversely affected water resources in locations around the country is not in dispute. Environmental regulatory agencies of three of the Commission's members (the United States, New York State and Pennsylvania) and multiple peer-reviewed journal articles have documented multiple such occurrences.

At the time of publication of EPA's final report on the impacts of the hydraulic fracturing water cycle on drinking water resources in December of 2016, Tom Burke, EPA science adviser and deputy assistant administrator of the agency's Office of Research and Development, affirmed that "we [EPA] found scientific evidence of impacts to drinking water resources *at each stage* of the hydraulic fracturing water cycle." (Tong, 2016; Ballotpedia, 2016). EPA identified "spills during the management of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources" as among the "combinations of activities and factors more likely than others to result in contamination of groundwater resources." (U.S. EPA, 2016a, pp. ES-3, ES-46, 10-3, and 10-23).

The New York State Department of Health ("NYSDOH"), after reviewing the draft Supplemental Generic Environmental Impact Statement and accompanying draft mitigation measures prepared by the New York State Department of Environmental Conservation ("NYSDEC"), advised its sister agency in 2014 that "surface spills potentially resulting in soil, groundwater and surface water contamination" were among the "potential adverse environmental impacts that can result from [HVHF] which may be associated with adverse public health outcomes."(NYSDEC, Executive Summary, 2015, p. 2). In reliance in part on NYSDOH's conclusions, NYSDEC, distinguishing HVHF from other industrial activities that entail risks from chemical spills, found:

> The number of well pads and associated high-volume hydraulic fracturing activities could be vast and spread out over wide geographic areas where environmental conditions and populations vary. The dispersed nature of the activity magnifies the possibility of process and equipment failures, leading to

> the potential for cumulative risks for exposures and associated adverse health outcomes.

(NYSDEC, 2015b, pp. 28-29). The U.S. Geological Survey, the science agency for the U.S. Department of Interior, in its response to a request for information from the DRBC, responded in part that:

> [a]cross the Nation, surface spills and accidents of UOG [unconventional oil and gas] wastewaters tied to wastewater disposal activities and transport have been documented to contaminate water resources. This indicates that there is a strong likelihood that some contamination of water resources will occur if drilling is permitted within the Delaware River Basin (DRB).

(USGS, 2018, p. 17). The findings set forth above are based on dozens of reliable investigations, many of which are referenced in the discussion below.

Key Facts and Assumptions About Spills

For the purposes of this response to comments document, "spills" are considered to be accidental, unintended or unlawful releases of chemicals, drilling and/or fracturing fluids, flowback and produced water, and other materials used and/or generated through HVHF. In its 2015 study of spills, EPA identified and characterized HVHF-related spills, providing a list of the types of spilled materials (see Table 2) (U.S. EPA, 2015e, p. 14). EPA's assessment found that flowback/produced water was the most common type of fluid spilled and that such spills represented the largest volume of spilled substances (85 percent) (U.S. EPA, 2015e, p. 13). Spills can result from, among other things, human error, equipment failure, poor management and planning, and illicit dumping. In the relevant studies and literature, the terms "spill" and "release" are often used interchangeably. Some spills are contained, and contaminants do not in all instances reach the soil, groundwater or surface water. A spill may be as small as a few gallons and relatively harmless or, depending on the toxicity of the material and its affinity to mobilize and reach environmental receptors, it may constitute a major event that threatens or pollutes nearby wetlands, streams or groundwater. In Pennsylvania, regulations require the self-

Material Type	Definition	Examples
Flowback and produced water	Fluids that return after the pressure applied during hydraulic fracturing is released	Flowback, flowback containing oil, produced water, produced water containing condensate, saltwater
Fracturing fluid	Fluid injected downhole	Frac sand, frac fluid (containing gel), frac fluid (containing WFR-55LA, WBK-143L, BIO5000), frac fluid with diesel* (containing HCl, clay, stabilizer, diesel, friction reducer), KCl water
Chemicals and products	On-site materials used in hydraulic fracturing fluids	Acid, KCl,† biocide (diluted), friction reducer, scale inhibitor, cross-linker (BC-200UC), WGA15, gel
Frac water§	Water used in hydraulic fracturing operations; may be recycled, treated, or untreated	Treated frac water, untreated frac water
Hydrocarbons	Petroleum-related fluids released through hydraulic fracturing operations	Diesel, oil, petroleum, condensate, gas well liquid
Equipment fluids	Fluids from on-site equipment involved in hydraulic fracturing activities	Antifreeze, hydraulic fluid, diesel
Unknown	Unknown which fluid type was spilled; not reported	Unknown

* "Diesel" is included in both "fracturing fluid" and "equipment fluids" categories. "Frac fluid with diesel" was considered a fracturing fluid, whereas "diesel" was placed under equipment fluids if it was related to on-site equipment.

† "KCl" is included in both "chemicals and products" and "fracturing fluid" categories. "KCl" was considered a chemical, whereas "KCl water" was considered a fracturing fluid.

§ Unlike fracturing fluid, frac water may not include individual chemicals and/or chemical products, whereas fracturing fluid is expected to contain individual chemicals and/or chemical products.

Table 2: Types of Spill Materials

reporting of spills and releases, and whether a specific spill meets the mandatory reporting criteria historically has been open to some interpretation. Under Pennsylvania's regulations governing unconventional wells, an operator or other responsible party must report the following types of events:

- A spill or release of a regulated substance causing or threatening pollution of the waters of the Commonwealth, or
- A spill or release of 5 gallons or more of a regulated substance over a 24-hour period that is not completely contained by secondary containment.

See, 25 Pa. Code § 78a.66(b)(1).

Many factors influence the severity of impacts on water quality due to spills and releases, including the amount and toxicity of the spill, the topography and geology at the spill site, and the distance to and characteristics of the receiving water.

Unless these factors are known, the impacts of an HVHF spill can be difficult to predict. Site-specific studies of hydraulic fracturing wastewater releases highlight the role of local geology in the movement of produced water through the environment. For instance, at a site in Kansas, low permeability soils and rock caused produced water to flow over the land surface to nearby surface waters, reducing the amount of produced water that infiltrated soil. In contrast, produced water and oil from two pits in Oklahoma flowed through thin soil and into the underlying, permeable rock. Produced water was also identified in deeper, less permeable rock. The investigators of the Oklahoma event have suggested that produced water moved into the deeper, less permeable rock through natural fractures. These studies highlight the role of preferential flow pathways in the movement of produced water through the environment. *See*, U.S. EPA, 2016a, p. ES-37 (*citing,* Whittemore (2007) and Otton *et al.* (2007), respectively).

The risk of spills associated with HVHF is characterized by the dispersal of well pads across the landscape, the need for hundreds of truck trips – often on unpaved and/or temporary roads – to move materials and equipment to and from these remote sites during each phase of the exploration and extraction process, and the proximity of drilling locations to sensitive water resources, including headwater streams and wetlands. Within the Delaware River Basin, the region underlain by natural gas-bearing shale formations drains to portions of the non-tidal river that the Commission has classified as "Special Protection Waters" due to their exceptionally high quality, diverse aquatic life, and value as a source of drinking water and for scenic and recreational uses. These characteristics distinguish this industry from any that has preceded it in the Basin since the onset of the industrial era.

The highly mobile and decentralized nature of unconventional oil and gas operations entails the storage and use of hazardous substances throughout the landscape, often in farm fields, forests and other relatively remote and widely distributed locations in ways that are not shared by many traditional commercial enterprises. The dispersed location of well pads and hydraulic fracturing operations require more vehicular trips that in turn increase the probability of accidents and mishaps. The phased nature of the activity may result in frequent turnover in personnel and varying levels of oversight. Unconventional drilling activities involve greater inherent risk of mechanical problems than conventional drilling operations (Chesapeake Energy Corp., 2016, p. 17). The scattered nature of these operations, coupled with the need to transport raw materials and wastes (U.S. EPA, 2016a, p. 7-40), raises the potential for spills of related materials to reach and contaminate environmental receptors, including soil, wetlands, ponds, lakes and streams, and ground water. *See, e.g.,* Patterson *et al.,* 2017; Lauer *et al.,* 2016; Maloney *et al.,* 2016; U.S. EPA, 2016a, pp. 5-1, 5-44, 5-45; U.S. EPA, 2015e, pp. 19-20; PADEP, 2017d; PADEP, 2014c; Considine *et al.*, 2012.

Finally, studies of hydraulic fracturing-related spills in the U.S., including in Pennsylvania, note limitations in relevant, available data, which has led to the suggestion that spill incidents are likely under-reported and/or not clearly or comprehensively characterized. *See,* Patterson *et al.,* 2017; U.S. EPA, 2015e, p. 26; Brantley *et al.,* 2014; Rahm and Riha, 2014. In Pennsylvania, self-reporting is required when HVHF spills or releases meet the criteria applicable to unconventional oil and gas operations (i.e., when a spill exceeds a specified volume and/or threatens to pollute "waters of the Commonwealth"). According to PADEP staff, spill reporting requirements have evolved as industry practices, drilling intensity, and the agency's understanding concerning related risks and impacts developed over time, and stringent spill reporting requirements have been in place in varying forms since 2001. In response to criticism that whether a release meets the reporting criteria is open to interpretation, the agency suggests that the compliance liability associated with failing to report is significant. *See* PADEP, 2013a (technical guidance for spill reporting at oil and gas well sites or access roads), p. 3 ("recommended policies to avoid operator liability for failure to properly report spills and releases," but "not requirements"); *also see, generally,* PADEP, 2013b (Comment and Response Document on technical guidance document 800-5000-01). PADEP staff have also suggested anecdotally that HVHF-related spills may be over-reported due to the perceived legal implications that attach to inadequate notification, and also as a subtle way that operators protest reporting guidelines perceived as overly burdensome.

Key Spill Studies

The EPA recognized in its 2016 report on the impacts of the hydraulic fracturing water cycle on drinking water resources in the United States that spills during the management of hydraulic fracturing fluids and chemicals or produced water may result in large volumes or high concentrations of chemicals reaching groundwater resources, placing spills among the hydraulic fracturing activities and factors that EPA has identified as more likely than others to result in contamination of groundwater resources (U.S. EPA, 2015a, p. ES-3). Spilled, leaked or released substances, including chemicals, additives, flowback and produced water, associated with the hydraulic fracturing process can flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers (NYSDEC, 2015a, p. 6-15). Multiple incidents of this nature have been well documented by the EPA, the PADEP, the U.S. Geological Survey, and others. *See e.g.,* Cozzarelli *et al.,* 2017; McLaughlin *et al.,* 2016; U.S. EPA, 2015e, pp. 19-20, 27; Brantley *et al.,* 2014; and Rahm and Riha, 2014.

According to a 2014 study, a review of the PADEP's violation database in 2012 showed that shale gas development-related spills on land and those that impacted surface water together made up the largest number of incidents of environmental concern (Rahm and Riha, 2014). Although surface water resource impacts have been documented, site-specific studies that could be used to describe factors affecting the frequency or severity of impacts are limited. The study authors noted:

> A more recent analysis again found spills, defined as any unintended release of fluids or waste at the surface, the most common violation type issued, with 5 to 20 violations issued for every 100 wells drilled between 2008 and

> 2013. . . . Unfortunately, a vast majority of violation entries had insufficient data to determine spill size, location, cause, or environmental impact. What was clear was that some operators had better violation records than others, and that adherence to best management practices occurred at some times, and not others.

(Rahm and Riha, 2014)(internal citations omitted).

After several years of exhaustive study on the potential environmental and human health impacts of HVHF-related activities and how to mitigate them, New York State determined that prohibiting HVHF statewide was the appropriate course, in part due to the risks to water resources associated with inadvertent releases. The environmental impacts statement upon which New York's determination was based found that:

> Adverse impacts to water resources might reasonably be anticipated in the context of unmitigated high-volume hydraulic fracturing due to: . . . 2) polluted storm water runoff; 3) surface chemical or petroleum spills; 4) pit or surface impoundment failures or leaks; . . . and 6) improper waste disposal.

(NYSDEC, 2015a, p. 6-1). Noting the significant number of contaminants associated with HVHF operations, the Finding Statement that completed New York's environmental quality review process further commented that "[t]hese additives and contaminants could result in significant adverse public health and environmental impacts if spilled or released taking into account potential exposure pathways." (NYSDEC, 2015b, p. 12).

Chapter 5 of the Final SGEIS, informed by input from the New York State Department of Health, described potential adverse health impacts from exposure to classes of chemicals such as petroleum distillate products, aromatic hydrocarbons, glycols, alcohols, aldehydes, microbiocides, and other constituents (NYSDEC, 2015b, p. 12)(referring to NYSDEC, 2015a, pp. 5-67–5-72).

The SGEIS Finding Statement noted that:

> Spills or releases of these contaminants can occur as a result of tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, improper operations and other incidents. Spilled, leaked or released fluids could flow overland to a surface water body or infiltrate the ground, reaching subsurface soils, aquifers, and drinking water sources. These types of environmental impacts could lead to significant and adverse public health outcomes.

(NYSDEC, 2015b, p. 12). The potential impacts associated with HVHF spills examined in the New York State DEC's final SGEIS included:

> 1) [p]otential degradation of NYC's surface drinking water supply; 2) [p]otential groundwater contamination from the hydraulic fracturing procedure

> itself; and 3) [a]dverse impacts to the Upper Delaware Scenic and Recreational River.

(NYSDEC, 2015a, p. 6-1).

According to the U.S. Geological Survey, if HVHF is permitted, there is a strong likelihood that spill events will occur, including in the headwaters of the Delaware River Basin, and that water resources will be negatively affected (USGS, 2018, p. 17).

Spills pose a risk during every phase of the hydraulic fracturing process—on or near the well pad during drilling and completion of a well; during the mixing, injection, recovery and storage of fracturing fluids and formation water following well stimulation activities (the most prevalent source of HVHF spills, according, for example, to U.S. EPA, 2015e, pp. 1, 2, 13, 15-17); and during the production stages of shale gas development. In its 2015 study of hydraulic fracturing-related spills, the EPA detailed the storage and handling issues that can lead to spills at well pad sites:

> Hydraulic fracturing base fluids, most commonly water, are typically stored in large volume tanks on the well pad. Chemicals additives can be stored on a flatbed truck or van enclosure that holds a number of chemical totes. The most common chemical totes are 200 to 400-gallon polyethylene containers. Pumps and hoses are used to move the base fluid and chemical additives to a blender that mixes the fluids. The fluid is then transferred to a manifold for delivery to the wellhead for injection. As fluids are transferred and moved around the well pad and through various pieces of equipment, faulty equipment or human error may create opportunities for spills of the various components of fracturing fluid.

(U.S. EPA, 2015e, p. 3)(internal citations omitted).

Spills occur during the storage and processing of materials on or near the well pad site and as a result of blow-offs from the wellhead during drilling or production, transfers of material between pieces of equipment through flowlines, and transport via vehicle or transmission lines. Drilling mud spills and, if disposal wells are employed, spills associated with disposal through underground injection control wells also are of concern (USGS, 2018, pp. 17-18; Patterson *et al.,* 2017).

More than one thousand different chemicals are reportedly used for hydraulic fracturing across the United States, although often between three and twelve chemicals, dependent on geology and operator, are stored, blended, and used to develop an individual unconventional well (U.S. EPA, 2016a, p. 5-3; U.S. DOE, 2009, p. 61). Information on some of the chemical components, agents and additives used in hydraulic fracturing frequently is withheld by the well operator or manufacturer as confidential business information (see more on Chemical Disclosure in Section 2.6.2). Produced water that is generated during unconventional natural gas production possesses variable toxicity; more importantly, even where the constituents are disclosed, the toxic effects of many of these substances are unknown and critical information about their effects continues to emerge.

Characterization of Substances that Comprise Hydraulic Fracturing Spills

While the proportion of chemicals used in the hydraulic fracturing process is relatively small compared to other components (e.g. the fluid base and proppant), the volume of chemicals and other agents added can be significant due to the quantity of water used to fracture each well. These substances, combined with constituents present within the formation into which the fluid solution is injected, become components of the large volumes of complex residual wastes generated in the processes of well drilling/completion, hydraulic fracturing and production. The chemicals added to facilitate well drilling and recovery of the mineral resource include, but are not limited to, biocides, corrosion inhibitors, friction reducers, scale inhibitors, and degreasers), and the substances and compounds mobilized from the target formation include hypersaline brines and naturally occurring radioactive materials. *See,* USGS, 2018, p. 17; U.S. EPA, 2016a, pp. 5-8 – 5-19.

Not all of the chemicals and additives used in hydraulic fracturing have been identified, and only a subset of the identified substances have established toxicity values, according to the EPA (U.S. EPA, 2016a, pp. ES-44-45, 9-1). For instance:

> Of the 1,606 chemicals identified by the EPA in hydraulic fracturing fluid and/or produced water, 173 had toxicity values from sources that met the EPA's criteria for inclusion in this report. Toxicity values from these selected data sources were not available for 1,433 (89%) of the chemicals . . . . Given the large number of chemicals identified in the hydraulic fracturing water cycle, this missing information represents a significant data gap that makes it difficult to fully understand the severity of potential impacts on drinking water resources.

Id., pp. ES-45-46. However, depending on the concentrations and synergistic effects of chemicals during exposure, the potential human health effects of known substances used and generated by hydraulic fracturing include toxicity to multiple human organs, sensitization, irritation, developmental effects, and tumor promotion (Kassotis *et al.,* 2018). (More on toxicity appears below.)

Following stimulation of an unconventional gas well (i.e. injection of fracturing fluids under high pressure into the target formation), residual fluids return to the surface. Most of the fluids injected during hydraulic fracturing remain underground, locked within the target formation. (The issue of "consumptive water loss"—or the portion of water lost to the hydrosphere—is addressed in Section 2.3.2.1, Water Use). A fraction of the injected solution, however, returns to the surface, along with recovered minerals, as flowback/produced water.[22] Flowback commonly refers to the initial return of fluids to the surface and consists predominantly of substances injected into the well during the hydraulic fracturing process. In contrast, produced water refers to the material that emerges after the initial "flowback" and during the production phase, when the targeted hydrocarbon minerals begin to be recovered at the wellhead (AGI, 2019). For the purposes of this document, we generally

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[22] EPA reported that wells in the Marcellus Shale typically yield 10-30% of the injected volume as produced water in the first 10 years after hydraulic fracturing. (U.S. EPA, 2016a, pp. ES-14 (Figure ES-4(a)), ES-34, 7-1). Thus if 16,000,000 gallons of fluid are injected, between 1.6 million and 4.8 million gallons will be returned over that period and must be managed.

consider flowback as a component of produced water, and references to the latter should be construed as encompassing both. (Also see Appendix-2 for a glossary of wastewater terms).

The substances that return to the surface as produced water contain a complex array of chemical compounds and minerals that include the injected base fluids, compounds formed when those fluids react with, degrade or transform geological material underground, and formation water that may consist of salts, metals and radioactive materials (Kondash *et al.,* 2017; U.S. EPA, 2016a, p. ES-33). The produced water typically flows from the wellhead to on-site storage tanks, pits or lagoons before being transported offsite (via truck, rail or pipeline) for treatment, disposal and/or discharge. Increasingly, produced water is being treated on- or off-site and reused for subsequent fracturing operations. The Commission notes that the use of centralized impoundments to store unconventional well wastewater is no longer allowed in Pennsylvania unless the operator has obtained a residual waste storage permit.[23]

In its 2016 study, the EPA reported a range of 420,000 to 1.3 million gallons of produced water being generated per Marcellus unconventional well in the Susquehanna River Basin (U.S. EPA, 2016a, Figure ES-4a, p. ES-14).[24] Rahm *et al.* (2013) reported that during the initial ramp-up of unconventional natural gas development in the Marcellus Shale (between 2008 and 2011), approximately 6 million meters^3 (or nearly 1.6 billion gallons) of wastewater had been generated in Pennsylvania. In a review of data on flowback and produced waters in six of the major unconventional oil and gas formations in the United States, Kondash *et al*. report that the volume of produced water generated in the first five to ten years of production in unconventional oil or gas wells ranges from 0.5 to 3.8 million gallons (Kondash *et al.,* 2017). The higher range reported by Kondash includes more recent data from several unconventional formations around the country and thus may reflect the increasing volumes of water being used to hydraulically fracture oil and gas wells. The volume of water injected and the flowback and produced water returned to the surface from shale gas wells in Pennsylvania is expected to increase, due in part to the industry trend of extending the lateral portion of unconventional natural gas wells over longer distances and in part to the eventual need for longer vertical well bores to reach deeper shale formations, such as the Utica which lies below the Marcellus formation (Kondash *et al.,* 2018).

The USGS stated that the large volume of unconventional well production fluids, "with their complex chemistries, present water management challenges and pose risks to water resources via surface spills and accidents." (USGS, 2018, p. 17)(internal citation omitted).

Occurrences of Spills - National Perspective

Chapter 5 of the 2016 EPA Report, which was based upon an earlier 2015 EPA hydraulic fracturing spills report, provides a comprehensive assessment of hydraulic fracturing spill experiences in several states. The objective of this review was to characterize hydraulic fracturing-related spills that

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[23] Under rules finalized by PADEP in 2016, waste storage pits, lagoons and impoundments are more closely regulated (e.g. pit liners are now required) than when some of the significant HVHF spills summarized in this section occurred; thus, at least some of the historic spills/releases described or summarized in this section might have been prevented under current regulations.

[24] U.S. EPA (2016a) shows that wells in the Marcellus formation within the Susquehanna River Basin yield less produced water compared to unconventional wells located in the Barnett Shale in Texas.

could reach surface or ground water resources using reported spill data obtained from selected state and industry data sources. Data on spills that occurred between January 2006 and April 2012 were obtained from nine states with online spill databases or from other sources. Of the spills with sufficient information, the EPA identified 457 (approximately 1 percent) as related to hydraulic fracturing (U.S. EPA, 2015e, pp. 1-2, 19-20; U.S. EPA, 2015g).

Based on the data it examined the EPA found:

- Hydraulic fracturing-related spills consisted of numerous low-volume events (up to 1,000 gallons) and relatively few high volume events (greater than 20,000 gallons).
- The most common material spilled was flowback and produced water, and the most common source of spills was storage units.
- More spills were caused by human error than any other cause.
- There were 300 spills (66 percent of the 457 spills included in this study) in which spilled fluids reached at least one environmental receptor. Twenty-four of these spills reached multiple environmental receptors.
- Soil was the most commonly reported environmental receptor, with spilled fluids reaching soil in over half (64 percent) of all hydraulic fracturing-related spills.
- Spilled fluids were reported to have reached surface water in 32 hydraulic fracturing-related spills (7 percent);
- The median volume per spill for these spills was 3,500 gallons, and volumes per spill ranged from 90 gallons (5th percentile) to 45,000 gallons (95th percentile).
- Spilled fluids were reported as not reaching surface or ground water in 186 spills (41 percent).
- Of the spills that reportedly reached surface water, the cumulative reported spill volume exceeded 200,000 gallons.

Subsequent studies of hydraulic fracturing spills/releases around the country reported considerably more spill events than did the 2015 EPA study, which was narrow in scope and only looked at spills "occurring on or near the well pad." *See, e.g.* Patterson *et al.,* 2017; Lauer *et al.,* 2016; and Maloney *et al.,* 2016, all referenced separately herein. The EPA acknowledged the limitations of its study, the effect of which substantially reduced the potential universe of hydraulic fracturing-related spills during the study period, this way:

> Because the main focus of this study was to characterize hydraulic fracturing-related spills on the well pad that may reach surface or ground water resources, the following topics were not included: transportation-related spills,

> drilling mud spills, and spills associated with disposal through underground injection control wells.

(U.S. EPA, 2015e, p. 1). The EPA spills report goes on to say that "[t]he 457 spills used to characterize hydraulic fracturing-related spills were likely a subset of the total number of hydraulic fracturing-related spills that could have been identified from the state and industry data sources." (U.S. EPA, 2015e, p. 26).

To gain a clearer picture of hydraulic fracturing-related spill risk, Patterson *et al.* (2017) reviewed spill data for four states—Colorado, New Mexico, North Dakota and Pennsylvania—where unconventional oil and gas (UOG) extraction is prevalent. Patterson's findings for these states provide an indication of possible outcomes in the Delaware River Basin. The investigators found that:

> Between 2005 and 2014 there were 6648 spills reported across the four states based on each state's reporting requirements and our definition of UOG wells. . . . Our results exceed the number of spills found by EPA (n = 457) for eight states between 2006 and 2012 because we included spills that occurred during all stages of unconventional production (from drilling through production) while EPA focused on those spills explicitly related to hydraulic fracturing.

The researchers in this study also noted that 75-94 percent of the spills they identified "occurred within the first three years of when wells were drilled, completed, and had their largest production volumes." Finally, the study report documented that across all four states studied, 50 percent of spills were related to the storage or transportation of fluids.

In North Dakota, which had the greatest number of hydraulic fracturing-related spills reported by Patterson *et al.* (2017) (n=4,453), spills of highly saline produced and flowback water have increased significantly from 2006 to 2014 (Sontag and Gebeloff, 2014). Similarly, Lauer *et al*. (2016) report approximately 3,900 "brine spills" from unconventional oil activity in North Dakota between 2007 and 2015 and go on to point out that such spills "are directly associated with recent unconventional oil extraction" rather than conventional oil and gas production. A study led by the U.S. Geological Survey (Cozzarelli *et al.,* 2017) reported more than 8,000 spills of fluid associated with unconventional drilling activity in North Dakota between 2008 and 2015. Based on its own analysis of state regulatory data concerning hydraulic fracturing-related spills in North Dakota between 2006 and 2014, *The New York Times* reported that more than 18 million gallons of oil, brines and chemicals had been spilled or leaked (Sontag and Gebeloff, 2014).

In 2015, nearly three million gallons of highly saline produced water leaked from a transmission line into the Blacktail Creek, a small tributary of the Missouri River. As part of a study led by the U.S. Geological Survey, geochemical and biological sampling performed downstream during remediation efforts found numerous persistent effects, including boron and strontium concentrations and radium activities up to 15 times greater than background levels in sediment, reduced fish survival, and estrogenic inhibition (Cozzarelli *et al.,* 2017). (The effects of this spill are discussed in greater detail in the section on water resource impacts below). About one year after the incident, a new leak detection system identified a leak in the same pipeline. Although crews were able to shut down the flow within 15 minutes, more than 7,000 gallons of produced water were released (Dalrymple, 2016).

In a 2016 study of oil and gas well spills on water quality, Lauer *et al*. (2016) noted that:

> In North Dakota, the high occurrence of OGW [oil and gas wastewater] spills is potentially threatening the quality of surface and drinking water resources. Since the beginning of the rise of unconventional oil extraction and hydraulic fracturing in 2007, there have been approximately 3900 brine spills reported to the North Dakota Department of Health by well operators. … OGW is primarily transported by pipes or trucks and stored in enclosed containers onsite prior to disposal. … Reported spills often occur during transport to injection sites via pipelines or during filling or emptying of storage tanks. Unlike other areas in the U.S. where decades of conventional oil and gas exploration have generated a legacy of contamination, … recent OGW spills are directly associated with recent unconventional oil extraction.

There is no evidence that the number of spills associated with the industry is declining. The explosion at a well pad owned by XTO Energy near Powhatan Point, Ohio on February 15, 2018, damaged the wellhead and caused the loss of control of the well for 19 days. The accident resulted in the release of over 5,000 gallons of HVHF fluid into a tributary of the Ohio River (U.S. EPA, 2018a), an estimated 2 billion cubic feet of natural gas to the atmosphere, and the evacuation of 94 residences (DiSavino and Palmer, 2018). Reportedly caused by a pressure buildup resulting in failure of the well casing (Grego, 2019), the Powhatan Point incident is particularly troubling because it followed several years of progress in the development of industry standards and best practices. In comments opposing DRBC's proposed rules, submitted one month after the incident, API pointed to "significant improvements to system integrity, reliability, and integrated safety." (API, 2018, pp. 1-2).

The need to manage large volumes of chemicals and production fluids in high volume hydraulic fracturing—including storage, transfer and handling on the well pad as well as transportation off-site for treatment, disposal and/or reuse—creates multiple opportunities for spills.[25] Based on a study of approximately 3,900 documented unconventional oil and gas (UOG) brine spills in North Dakota, Lauer *et al.* concluded that "[p]ipeline leaks made up 18 percent of the spill events and were responsible for 47 percent of the spilled water by volume," and the balance were the result of "valve/piping

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[25] Upon completion of hydraulic stimulation, flowback returns to the surface in large volumes at high flow rates, requiring extensive management (Mouser, 2019, p. 12). Flowback fluids are depressurized and conveyed through surface piping to temporary steel storage containers. In a typical example at a site in Pennsylvania described by Mouser, twenty 21,000-gallon tanks were to be used for this purpose. Assuming 20 percent of injected fluids in this example are returned to the surface as flowback or produced water, (4×10^6 gallons), an estimated 500 tanker truck loads of wastewater (8,000 gallons each) would be hauled off the site for treatment or disposal. (*Id.*) When flowback diminishes and production begins, Mouser explains, surface piping moves flowback and produced water from the wellhead through gas-water separators to tanks. Initially, these are temporary storage containers and later, permanent above-ground storage containers, which range in size from 12,600 to 42,000 gallons. Produced water is collected and managed for the remaining productive life of the well (20-50 years). (*Id.*) If condensate and/or oil are co-produced with the natural gas, similar permanent storage tanks are installed to hold liquid hydrocarbons until off-site transport (*Id.,* p. 13). Regarding management of produced water on the well pad, *see also*, EPA 2016a, p. 7-126, *citing* Gilmore et al., 2013 and GWPC and IOGCC, 2014 ("Failure of connections and lines during the transfer process or the failure of a storage tank can result in a surface release of fluids").

connection leaks (20.5 percent of volume, 24.8 percent of frequency) and tank leaks and overflows (14.5 percent of volume, 22.4 percent of frequency)."(Lauer *et al.*, 2016 (internal citations omitted)).

In their study of the effects of spills on agricultural soil in Colorado, McLaughlin *et al*. found that surface spills on site or during transportation were the most commonly reported causes of contamination (McLaughlin *et al.*, 2016). Relying on the Colorado Oil and Gas Conservation Commission (COGCC) database as the most complete in that state, they found that 838 spills were reported in 2014 alone,[26] resulting in the release of more than 660,000 gallons of flowback and produced water. Ninety-three (93) of these spills contaminated groundwater while eight (8) contaminated surface water. Six hundred-four (72 percent) of these spills were not contained on the well pad, suggesting that either soil and/or water were impacted (McLaughlin *et al.,* 2016). The number and consequence of spills reported by McLaughlin *et al.* are likely under-reported due to limitations in reporting requirements to the COGCC – we address this issue under "Data Gaps and Limitations" below.

Occurrences of Spills in Pennsylvania

According to the EPA, 19 percent (87 of 457) of the HF-related spills it identified for the period 2006 – 2012 occurred in Pennsylvania, based upon data retrieved from state and industry sources (U.S. EPA, 2015e, p. 10). Of the 87 reported spills in Pennsylvania,[27] 59 were of "unknown" volume. The volumes of the remaining spills were reported as between 5 and 7,350 gallons; and 45 of them (52 percent) were reported to consist of "flowback and produced water" (U.S. EPA, 2015e, Appendix B).

Examples of reported spills in Pennsylvania include the following:

2009 – Four uncontrolled releases reached surface waters and adversely affected local fish populations (Considine *et al.,* 2012; PADEP, 2014c):

- In Dimock, PA, 8,000 gallons of produced water spilled into Stevens Creek due to the failure of a supply pipe. The contamination caused a fish kill and impacted nearby wetlands.
- The failure of a supply line connection resulted in a spill of 10,500 gallons of partially recycled flowback water to Brush Run Creek, Hopewell Township, Washington County, resulting in the death of 300 small fish.
- A failed cap on a holding tank resulted in the release of approximately 8,000 gallons of produced water into Little Laurel Creek in Clearfield County, a waterway that is heavily fished for recreation.
- In Bradford County, an uncontrolled spill of up to 6,300 gallons of fracturing fluid entered an unnamed tributary upstream from a fishery.

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[26] Includes spills and releases of flowback and produced water that are 1 barrel (159 L) or larger outside and 5 barrels (795 L) or larger inside well pad berms.

[27] Pennsylvania regulations provide that an operator or other responsible party "shall report … (ii) A spill or release of a regulated substance causing or threatening pollution of the waters of the Commonwealth . . . ." (25 Pa. Code § 78a.66(b)1).

2010 – The discharge of hydraulic fracturing-related wastewater from well pad containment resulted in large volumes of contaminants into the air and/or onto the ground and surface waters:

- A blowout at the Punxsutawney Hunt Club in Clearfield County, PA projected 35,000 gallons of natural gas and drilling wastewater into the air and onto the ground over the course of 16 hours (Considine *et al.,* 2012; Maykuth, 2010).

- A leaking fluid containment basin and a discharging storage tank at a well pad site in Penn Township, Lycoming County, resulted in the release of between 22,000 and 57,000 gallons of produced water which impacted unnamed tributary to Sugar Run. Consequent sampling of the water body revealed elevated levels of chlorides, barium, strontium, and total dissolved solids (PADEP, 2016b).

2011 – The following incidents occurred as a result of equipment failure and/or operator error:

- In Bradford County, PA on April 19, 2011, thousands of gallons of HVHF fluid flowed onto the pad, overwhelmed containment measures and discharged into the Towanda Creek, a tributary of the Susquehanna River (Gilliland, 2011; Legere, 2011).
- Equipment failure on a well pad in Tioga County on January 17, 2011, resulted in a discharge of 21,000 gallons of production fluid within Pennsylvania State Forest lands (Detrow, 2012; MDN, 2012).

- An estimated 6,300 gallons of production fluid was discharged in Susquehanna County on January 10, 2011, due to a valve which was left opened (Considine *et al.,* 2012).
- On October 31, 2011, an operator's failure to contain and control hydraulic fracturing fluid resulted in the release of approximately 16,800 gallons of diluted wastes onto the ground and into Dunkle Run in Hopewell Township, Washington County (PADEP, 2014c).
- On March 15, 2011, a storage tank valve on a well pad in Tioga County was left opened, resulting in the release of 5,300 gallons of produced water into a stream carrying the state's "HQ" (high-quality) designation. The operator was cited for negligence and failure to report in a timely manner. The event was considered major given the volume of the spill and the impact on the environment (Considine *et al.,* 2012).
- Multiple spills and leaks at a well pad, drill pit, and impoundment site during a two-year period contaminated two springs in Washington County, Pennsylvania. *See, Kiskadden v. Pa. Dep't of Envtl. Prot.*, EHB 2011-149-R (June 12, 2015), pp. 3-4,; 149 A.3d 380, 395 (Pa. Cmmw. Ct. 2016).

2012 – According to PADEP, a structure designed as a freshwater impoundment pond at Phoenix Pad S in Duncan Township, Tioga County, was instead used to store produced water from hydraulic fracturing operations. The pond developed multiple leaks (it was later discovered that hundreds of holes had developed in the basin's liner), resulting in a "significant amount of waste released by its leaking six-million-gallon impoundment." (PADEP, 2014a). The discharge adversely affected soils, tributaries to Rock Run, groundwater seeps and vegetation (Williamsport Sun-Gazette, 2014; PADEP, 2017d).

2013 – Two significant events involving the discharge of natural gas and/or production fluid include:

- A malfunction with equipment on a well pad in Washington Township, Wyoming County resulted in the uncontrolled release of an estimated 227,000 gallons of production fluid over approximately eighteen hours. Although the discharge was contained on-site and no related air or water quality impacts were reported, the incident resulted in the evacuation of several nearby residences (Cusick, 2013a; Cusick, 2013b; Legere, 2013; PADEP, 2014b).
- On April 30, at the Mazzara well in Washington Township, Wyoming County, about 9,240 gallons of production water spilled outside the company's containment area, eventually spreading to fields used for livestock grazing and into the basement of a neighboring home (Hess, 2014; PennLive, 2014).

2014 – On February 11, 2014, three gas wells exploded at a well pad site in Dunkard Township, Green County, Pa. The explosion and ensuing fire, which burned uncontrolled for several days, killed one worker and injured another, resulted in the release of an estimated 10 to 25 million cubic feet of gas per day over nearly two weeks as well as the discharge of production fluids for up to eight (8) days (PADEP, 2015c; Colaneri, 2014a).

2017 – More than 63,000 gallons of natural gas drilling waste spilled into an unnamed tributary of the Loyalsock Creek from a well site in Lycoming County. The spilled fluid was filtered and treated "flowback" wastewater from an unconventional natural gas well following hydraulic fracturing (Frazier, 2017a).

Other researchers have studied hydraulic fracturing spills in Pennsylvania. Brantley *et al.* (2014) conducted an extensive review of available spills data from Pennsylvania between 2005 and 2013, utilizing a variety of sources, including PADEP's online database, personal field observations, PADEP office reports, and multiple media sources. The researchers highlighted the limitations on availability of data with respect to the occurrences, severity, and impacts of spills (a topic discussed in greater detail below). In some cases, information about spills provided by the PADEP and the media "were often difficult to reconcile at least in part because DEP records are generally terse with respect to the extent of impact." (Brantley *et al.*, 2014). The study report goes on to note that:

> If state regulator data are used to assess impact, the conclusion that emerges for PA is that significant environmental water resource problems are occurring at a low rate per well: ...~ 30 large spills were reported during the period when N6000 unconventional gas wells were drilled and N4000 completed . . . . In addition, the water supply contamination cases per year for both conventional and unconventional energy companies decreased since 2010. On the other hand, although the number of large spills per year associated with unconventional wells was small, it increased through 2012. In addition, almost

20% of shale-gas wells in PA have received Notices of Violations, documenting that the frequency of small incidents is high.

(Brantley *et al.,* 2014). As reported by Patterson *et al*. (2017) in their study of four states, Pennsylvania had the second highest number of reported spills at 1,293 during the period of review (2005-2014).

The PADEP provided DRBC with eleven years of reported spill data (2008-2018) (PADEP, 2019b). The data show an inverse relationship between the number of unconventional wells drilled and the number of oil and gas spills reported over the period. Specifically, while the number of new wells drilled decreased substantially over the period, the number of spills, generally, and those which involved flowback, brine and drilling fluid, specifically, increased dramatically (*see* Figure 13). However, PADEP officials informed DRBC that the upward trend in reported spills could reflect changes in reporting requirements and a greater compliance/enforcement presence in the field (*see* Appendix-4). This would suggest that reported spill incidents may have been underreported in the past.

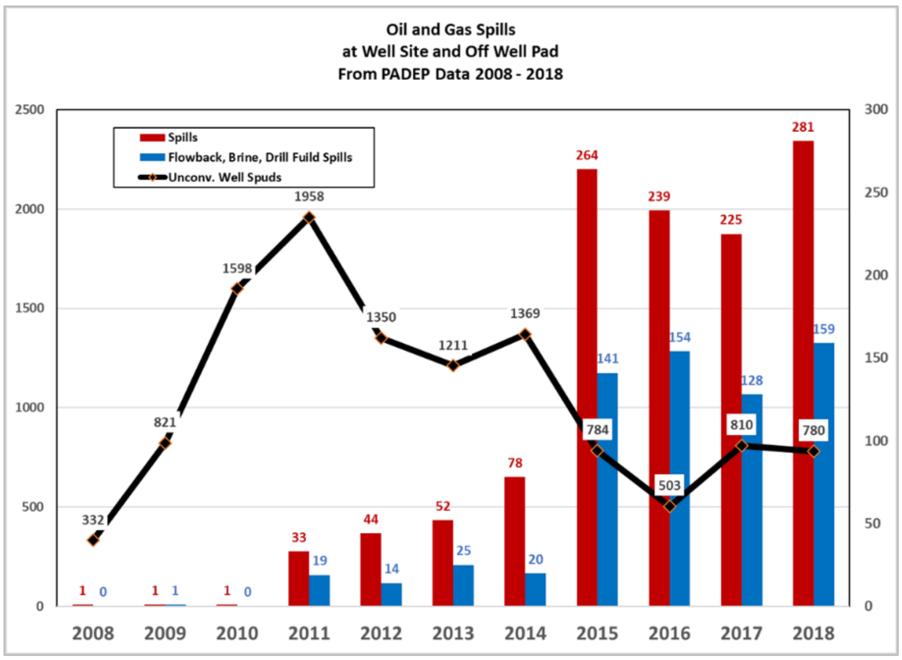

Figure 13: PADEP Data for 2008-2018 Oil and Gas Spills at Well Sites and Off Well Pads

Risk of Spills Associated with the Storage and Use of Chemicals and Additives

Some commenters suggested that the amount of chemicals injected into a well during the hydraulic fracturing process – and thus the risks to water resources from spills – is small. Although the chemical content of fracturing fluid may be small relative to the total volume of base fluid (water), the aggregated volume and concentration of additive chemical compounds and other agents used in unconventional oil and gas development are substantial. As EPA noted, "While the overall concentration of additives in hydraulic fracturing fluids is generally small (typically 2 percent or less of the total volume of the injected fluid), the total volume of additives delivered to the well site can be large." (U.S. EPA, 2016a, p. ES-22). The proportion of chemicals, additives, and/or ingredients within the injected solution during a single hydraulic fracturing event varies depending on the site- and operator-specific factors (U.S. EPA, 2016a, p. 5-3), such as characteristics of the targeted formation (e.g., rock type, temperature, and pressure), the economics and availability of desired additives, and well operator or service company preferences and experience (U.S. EPA, 2016a, p. 5-8; GWPC and ALL Consulting, 2009; FracFocus, 2019. In its review of the FracFocus database, the EPA noted concerning the concentration of additive substances other than water and proppant that "Among the entire data set, the sum of the maximum hydraulic fracturing fluid concentration for all additive ingredients reported in a disclosure was less than 1 percent by mass in approximately 80% of the disclosures, and the median maximum hydraulic fracturing fluid concentration was 0.43% by mass." (U.S. EPA, 2015a, p. 2).

In addition to the concentration of chemicals mixed into the injected solution during each fracturing event, recent studies have shown a progressive increase in the total volume of fluid used to hydraulically fracture unconventional natural gas wells, which in turn leads to a corresponding increase in the quantity of chemical additives injected and the volume of wastewater generated (Kondash and Vengosh, 2015). Wells may be fractured multiple times in order to re-stimulate and enhance mineral recovery. Kondash *et al.* (2018) concluded that:

> Between 2011 and 2016, water use for hydraulic fracturing and wastewater production in major shale gas and oil production regions generally has increased; although the figures for Pennsylvania are lower, the study found that water use per well increased up to 770%, while flowback and produced water volumes generated within the first year of production increased up to 1440%. The steady increase of the water footprint of hydraulic fracturing over time implies that future unconventional oil and gas operations will require larger volumes of water for hydraulic fracturing, which will result in larger produced oil and gas wastewater volumes.

Using data from the FracFocus Chemical Disclosure Registry[28] the American Petroleum Institute also found an increasing water use trend for each "HVHF treatment" in Pennsylvania, ranging from an average of 7.46 million gallons in 2013 to more than twice that volume, 16.04 million gallons, in 2017. The average volume of water used per well in the deeper Utica formation was nearly 20 million gallons in 2017 (All Consulting, 2018). The significance of increased water volumes per well directly relates to a corresponding increase in the volume of water and waste constituents that return to the surface and must be captured and properly managed, ultimately leading to the potential for a greater amount of produced water and chemicals that can be leaked or spilled.

Before the chemical mixing stage of the HVHF process and prior to mixture with a base fluid, chemicals are stored in concentrated forms on the well pad site. Based on the increasing volumes of fluid being used to hydraulically fracture wells in Pennsylvania, the quantity of chemicals and additive ingredients used to hydraulically fracture each well also likely have increased. USEPA reported an

[28] FracFocus.org is a publicly accessible website (www.fracfocus.org) through which oil and gas production well operators disclose information about the ingredients used in hydraulic fracturing fluids at individual wells.

estimated range of between 3,000 and 30,000 gallons of chemicals being used for each hydraulically fractured well between 2011 and 2013 (U.S. EPA, 2016a, pp. 5-27, 28), with up to twice that amount being stored on-site (U.S. EPA, 2016a, p. 10-12). Because water use volumes per well have increased dramatically (*see* Sec. 2.3.2.1 for further discussion on Water Use), the volume of chemicals and additive agents used to stimulate a single well may be up to ten times greater than that previously reported by the EPA.[29] If multiple wells are fractured per site, which is typically the case, thousands to hundreds of thousands of gallons of chemicals may be stored in vessels and containers at once or in stages and moved around the site via pipes, hoses, and tubes during the hydraulic fracturing of these wells (U.S. EPA, 2016a, pp. ES-22; 10-12). As noted above, these storage containers are a primary source of spills during the chemical mixing stage (although spills and releases also are attributed to wells/wellheads, pipes/hoses/lines, equipment and impoundments). Because on-site storage vessels often hold concentrated chemicals, spills from these containers, even in small volumes, may have serious impacts if they reach a drinking water source. Diluted chemicals may also spill during the chemical mixing process.

These additives may include a wide variety of biocides, corrosion inhibitors, friction reducers, and scale inhibitors. In some cases, chemicals, additives and agents used in hydraulic fracturing operations are considered confidential business information, and their identities and properties, by law, need not be disclosed to the public. Some commenters asserted that exemptions from disclosure present an added risk if these substances are spilled or released. *See* Section 2.6.2 concerning Chemical Disclosure Requirements.

The EPA identified 1,084 chemicals that were reported to have been used in hydraulic fracturing fluids between 2005 and 2013 (U.S. EPA, 2016a, p. ES-20). The toxicity, mobility and other properties of these chemicals varied widely. Some of these chemicals are likely to spread quickly through the environment with a spilled liquid while others tend to move more slowly because they bind to soil particles. Chemicals that move slowly through the environment may act as longer-term sources of contamination if spilled.

Again, the severity of potential impacts on water quality from chemicals released during spills depends on the identity and amount of substances that reach ground or surface water resources, the hazards associated with the chemicals, and the characteristics of the receiving water resource. Regarding the significance of chemical properties in influencing the potential impact of spills, EPA noted the following:

> Properties of the chemicals spilled also affect the frequency of impacts. We identified or estimated chemical and physical properties for almost half of the chemicals used in hydraulic fracturing fluids between 2006 and 2013 (455 of the 1,084 chemicals). These were individual organic chemicals, not inorganic chemicals, polymers, or mixtures. Volatility, solubility, and hydrophobicity/hydrophilicity are three properties, among others, affecting whether a

[29] EPA's estimated range of chemicals was based on a reported median 1.5 million gallons (5.7 million liters) of water being used per well from 2011 through early 2013 (U.S. EPA, 2016a, p. 4-1). As detailed in Sec. 2.3.2.1, Water Use, average water use per well in Pennsylvania for unconventional Marcellus/Utica wells, combined, was 16.04 million gallons in 2017 (All Consulting, 2018, Exhibit 21).

> spill reaches a drinking water resource (hydrophobic chemicals tend to repel or fail to mix with water, while hydrophilic chemicals tend to mix with water). The vast majority of organic chemicals in hydraulic fracturing fluid do not readily volatilize or evaporate, meaning these chemicals tend to remain in water if spilled. These chemicals also vary widely in their solubility and hydrophobicity/hydrophilicity, defying a general characterization. Nevertheless, of the 20 chemicals most frequently used according to our analysis of FracFocus, most are highly soluble and hydrophilic, meaning they will be mobile if spilled (Chapter 5). For example, methanol, isopropanol, and ethylene glycol are all likely to travel quickly through the environment. Thus, these chemicals may more frequently reach drinking water because of two unrelated, yet compounding factors: relatively high frequency of use in hydraulic fracturing operations and relatively high mobility in the environment.

(U.S. EPA, 2016a, p. 10-10).

According to the USGS, among the greatest risks of HVHF to the Basin are spills of fluids, both on a well pad and offsite, that could potentially contaminate surface and groundwaters and cause substantial harm to drinking water supplies and ecosystems (USGS, 2018, p. 20).

Risks to Water Quality and Uses from Surface Spills Associated with High Volume Hydraulic Fracturing

More compelling than the *number* of spills, described above, is the potential impact of those spills on waterways. Across the Nation, investigators have documented contamination of water resources resulting from surface spills and accidents associated with HVHF.

In their study of UOG spills in Colorado, North Dakota, New Mexico, and Pennsylvania, Maloney *et al*. related the proximity of reported spills to streams to the vulnerability of waterways. Reported spills on well pads in the four states were on average 580 meters (1903 feet) from a stream; however, distances between sites and streams were considerably shorter in Pennsylvania (268 meters/879 feet), and 5.3 percent of Pennsylvania spills were within required stream setbacks (30.5 meters/100 feet) (Maloney *et al.,* 2016). In their report, Maloney *et al*. highlighted that Pennsylvania's waterways were particularly susceptible for another reason:

> We found that spills in Pennsylvania occurred in watersheds with a much higher value to surface water than the other states, a result of higher population density and reliance on surface waters as drinking water in this area.

According to Maloney *et al*., 85 percent of spills in Pennsylvania occurred in watersheds which investigators classified as higher value, suggesting Pennsylvania is at greater risk for contamination of drinking water resources as a result of HVHF-related spills, given the location of hydraulic fracturing sites relative to freshwater resources. In instances when spills do not reach surface streams, they may result in pollution of groundwater resources. As of September 2020, 356 instances in which surface releases of HVHF-related substances have contaminated residential groundwater have been documented in PA (PADEP, 2019d; *also see,* Drollette *et al.*, 2019). For a discussion of impacts of

HVHF on drinking water supplies, see Section 2.3.3.1, Drinking Water Resources, of this Comment and Response Document.

Regarding the risk to water resources associated with spills and leaks of hydraulic fracturing and production fluids, Vengosh *et al.* (2014) noted that "Spills or leaks of hydraulic fracturing and flow-back fluids can pollute soil, surface water, and shallow groundwater with organics, salts, metals, and other constituents." In reporting on cases of suspected groundwater contamination from hydraulic fracturing, Vengosh *et al.* (2014) relate:

> A survey of surface spills from storage and production facilities at active well sites in Weld County, Colorado . . . showed elevated levels of benzene, toluene, ethylbenzene, and xylene (BTEX) components in affected groundwater.

In a study of domestic drinking water wells near oil and gas fields surrounding Pavillion, Wyoming, organic contaminants were detected, indicating migration from unlined pits that had been used to dispose of diesel-fuel-based drilling mud and production fluids (DiGiulio and Jackson, 2016). In their study of water impacts associated with spills of hydraulic fracturing wastes in North Dakota, Lauer *et al*. (2016) state that:

> Previous studies have shown contamination of local surface water resources from unconventional oil and gas development due to the release of OGW [(oil and gas wastewater)] to the environment in the form of (1) effluents to local streams and rivers following inadequate treatment by water treatment facilities, (2) dust suppressants and deicing agents, and (3) leaks and spills. The release of OGW to the environment has been linked to salt, trace metal, and NORM contamination of local surface water, shallow groundwater, and stream sediments.

(Internal citations omitted). In a study led by the U.S. Geological Survey of the three million gallons Blacktail Creek spill in North Dakota, Cozzarelli *et al.* (2017) reported:

- Samples collected during two time periods, February and June 2015, indicated the presence of wastewater markers and biological impacts in the river, which persisted for at least six months after the spill was discovered.
- These impacts were quantified through analyses of radioactive element (radium (Ra-226) and strontium) concentrations and isotopic compositions, trace inorganic and organic compounds, and endocrine-disrupting effects and bioassays with model organisms. Endocrine disrupting chemical (EDC) activity bioassays showed increased estrogenicity downstream suggesting the potential for reproductive effects.
- Concentrations of many wastewater-derived contaminants in stream water were several times greater than corresponding background concentrations.

- Sediment radium activity was significantly above the EPA action level for Ra-226 in surface soils.

Additional evidence of the effects of water resource contamination from accidents and surface spills indicative of the potential for contamination within the Delaware River Basin is provided below.

Maloney *et al*. (2016) noted the following examples of aquatic impacts from hydraulic fracturing spills:

> In Kentucky, an accidental release of hydraulic fracturing fluid into a stream increased gill lesions and other indicators of stress in fish, and in Pennsylvania, juvenile mussels below a brine treatment plant had lower survival rates than mussels located above the plant. Streambed microbial diversity was lower below an oil and gas waste injection plant in West Virginia, and water downstream from this site had higher endocrine-disrupting activities than reference water.

(Internal citations omitted). A study by the U.S. Geological Survey (McMahon *et al.,* 2017) reports that drinking water in the Eagle Ford, Fayetteville, and Haynesville Shale hydrocarbon production areas contained low concentrations of benzene, but at relatively high frequencies in the study areas. The highest benzene concentration detected in the water samples was 40 times lower than the federal drinking-water standard.

Grant *et al*. sampled 27 remotely-located streams in Pennsylvania's Marcellus Shale basin during June and July of 2012 and 2013. Their "results suggest fracking has the potential to alter aquatic biodiversity and methyl mercury concentrations at the base of food webs." (Grant *et al.,* 2016). The researchers also note that "[f]lowback water reaching streams can directly impact stream physiochemistry, as well as … limiting suitability for more sensitive taxa." (Grant *et al.,* 2016).

According to the United States Geological Survey, there is a strong likelihood that spills of wastewater associated with HVHF will reach and contaminate the water resources of the Delaware River Basin if this activity is permitted (USGS, 2018, p. 17). As discussed in Sec. 2.3.3.1, the impacts associated with releases of untreated HVHF wastewater (from spills and subsurface migration, for example) would likely be greater than the observed impacts from wastewater treatment plant discharges of oil and gas wastewater where that has occurred.

Radioactivity

A key characteristic of the waste stream generated during the HVHF process is radioactivity, which potentially represents a substantial risk to water resources, aquatic ecosystems and biota, and public health, if spilled or released. Extremely salty brines that are remnants of ancient seawater are often associated with organic-rich shales. The salts in shale waters reached extreme concentrations over millions of years, and their chemical interactions with the surrounding rock can mobilize radionuclides. A regional comparison of produced water salinities indicates that Appalachian Basin salinities are relatively high compared to other oil- and gas-producing formations in the United States (Rowan *et al.,* 2011).

Vidic *et al*. (2013) report that "The flowback and produced water from the Marcellus Shale is the second saltiest and most radiogenic of all sedimentary basins in the United States where large volume hydraulic fracturing is used." In their study of radium content in oil and gas-derived produced waters, Rowan *et al*. (2011) explain:

> Produced water salinities from reservoirs in rocks … in the Appalachian Basin commonly exceed 100,000 mg/L, and far exceed the salinities of many other oil- and gas-producing regions in the United States, including basins in California, the Great Plains, and Colorado Plateau. In many basins, radium activity is correlated with salinity, and … salinity may be used as an indicator of radium activity. The data compiled for Pennsylvania indicate a relationship similar to that described in other basins; total radium and Ra-226 activities are linearly correlated with TDS [total dissolved solids].

On the point of the relationship between salinity and radioactivity, researchers have documented that as injected fluids during hydraulic fracturing react with salts in the target shale formations (e.g. sodium, calcium, chloride and barium), they tend to extract more of the radium from the shale and allow it to flow to the surface (Landis *et al.,* 2018; Renock *et al.,* 2016). More simply, shale formations with relatively higher salinities, such as the Marcellus, may produce wastewaters with higher radionuclide concentrations.

Radioactive elements locked deep within the Earth or exposed at the surface due to a range of natural activity can be found in soils and in surface water, generally in trace amounts. These elements are referred to as "naturally occurring radioactive material" (NORM). When NORM has been modified by past or present human activities, such as through mobilization or concentration as a consequence of hydraulic fracturing, it is referred to as "Technically Enhanced NORM" (TENORM). EPA distinguishes NORM from TENORM as follows:

> (NORM) is defined as: Materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that are undisturbed as a result of human activities. . . . (TENORM) is . . . [n]aturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing

(U.S. EPA, 2008, p. ES-1).

As noted in the referenced example below, release of TENORM into the atmosphere or environment where it can accumulate and reside for thousands of years presents a range of handling, treatment, disposal, and exposure issues. If released or spilled through HVHF activities, the concentration and persistence of these radioactive substances presents a threat of toxic exposure and/or ingestion by humans and other living organisms.

Radium-226 and Radium-228, among other radioactive isotopes, are the principal radioactive agents found in the flowback and produced water that return to the surface during hydraulic fracturing. As a radioactive element, radium may represent a potential health hazard if released into the environment. USGS scientists reported that:

> The half-lives of the two principal isotopes of radium, Ra-226 and Ra-228, are 1,600 and 5.75 years, respectively, and approximately 10 half-lives are required for a radioactive element to decay to negligible quantities. Chemically, radium behaves in a manner similar to calcium and is capable of bioaccumulation in plants and animals. There is a significant body of research aimed at quantification of radium uptake in crops and livestock that make up the human food chain.

(Rowan *et al.*, 2011 (internal citations omitted)). According to the PADEP's 2016 Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) Study Report, sampling results of produced water from unconventional wells sampled in Pennsylvania revealed:

- The average concentration of Radium-226 was 8,344 pCi/L (unfiltered) and 8,219 pCi/L (filtered). The range of results was 1,520 to 26,600 pCi/L.

- The average concentration of Radium-228 was 986 pCi/L (unfiltered) and 985 pCi/L (filtered). The range of results was 366 to 1,900 pCi/L.

For a perspective on the above concentrations, the natural background radioactivity value for Radium-226 in U.S. soil is 1.1 pCi/L (PADEP, 2016b, p. 2-16), while the EPA maximum contaminant level (MCL) for combined Radium-266/-228 in drinking water is 5 pCi/L. *See*, 65 Fed. Reg. 76707 (Dec. 7, 2000).

In reporting on the observed levels of radioactivity from produced water and the threat from spills, Pennsylvania's TENORM study found that:

> There is little potential for radiological exposure to workers and members of the public from handling and temporary storage of produced water on natural gas well sites.
>
> However, there is a potential for radiological environmental impacts from spills of produced water from unconventional natural gas well sites and from spills that could occur from the transportation and delivery of this fluid.

(Perma-Fix, 2016, p. 9-2)(emphasis omitted).

A 2016 EPA Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category also characterized oil and gas produced water from the Marcellus Shale Formation. The radioactive constituents and concentrations identified were as follows:

- The median concentration of gross alpha was 8,700 pCi/L, with an observed range of 4.7 to 24,000 pCi/L. For comparison, the DRBC water quality criterion for gross alpha is 3 pCi/L.

- The median concentration of gross beta was 1,600 pCi/L, with an observed range of 0.66 to 1,700 pCi/L. For comparison, the DRBC water quality criterion for gross beta is 1,000 pCi/L.

Radium emits alpha particles, which are most dangerous when inhaled or ingested. Radium and radon emit alpha and gamma rays upon their decay, which kill and mutate cells. Long-term exposure to radium and its direct by-product, radon, internally or externally, can negatively impact human health, leading to certain types of cancer and other disorders (e.g. anemia, cataracts, and fractured teeth). Radium, via oral exposure, is known to cause bone, head, and nasal passage tumors in humans. Consuming radium in drinking water can cause lymphoma, bone and lung cancer, and leukemias. Human exposure to radioactivity in recreational water is also a valid concern. Accidental ingestion, inhalation, and in some cases dermal contact with radium isotopes in contaminated water, can have both carcinogenic and DNA-altering effects (Brugge and Buchner, 2012; ATSDR, 1990).

While not resulting from accidental spills and releases, discharges of both conventional and unconventional oil and gas production wastewaters, even following treatment, have proven problematic. Some of the constituents, including radioactive elements, accumulate in stream sediments and can persist for extremely long periods of time. One study found that, despite voluntary curtailment of oil and gas extraction wastewater discharges in Pennsylvania commencing in 2011, analysis of three discharge locations revealed significantly high levels of radioactivity compared to upstream locations. In fact, the level of radiation found in stream sediments at the disposal sites was about 650 times higher than radiation in upstream sediments. In some cases, it even exceeded the radioactivity level that requires disposal only at federally designated radioactive waste disposal sites (Lauer *et al.,* 2018).

Recently, elevated concentrations of strontium, an element associated with hydraulic fracturing produced water, have been found in the shells of freshwater mussels downstream from wastewater effluent discharges near the Allegheny River in Warren, PA (Geeza *et al.,* 2018). Shells from freshwater mussels collected upstream of oil and gas wastewater discharges and in the Juniata and Delaware Rivers (where there was no reported history of oil and gas discharge) showed little variability and no trends in strontium content over time (Geeza *et al.,* 2018). The Geeza *et al*. findings concluded, in part, that contaminants associated with oil and gas wastes likely bioaccumulated in areas where treated effluent was discharged to surface water.

For additional discussion of radioactivity in produced water, *see* Section 2.3.3.4, Pollution from Wastewater Handling and Disposal. For additional discussion of water quality impacts associated with the discharge of both conventional and unconventional wastewater from treatment plants in Pennsylvania, *see* Section 2.3.3.2, Surface Waters and Aquatic Life, and specifically, response R-59.

Spill Toxicity and Potential Human Health Effects

Human health impacts from HVHF production may result if exposure occurs due to the release of hydraulic fracturing-related chemicals, agents, and wastewater due to spills during drilling, well completion/stimulation, and production activities, or improper handling, storage, transport, or disposal. Water resource contamination from hydraulic fracturing-related spills also presents potential challenges for drinking water treatment since an array of chemicals and other agents present in these wastewaters can accumulate in source waters of public water supplies and require advanced and costly treatment or jeopardize treatment efficacy altogether. For a more detailed discussion of the impacts of HVHF on drinking water, *see* the response to comments related specifically to drinking water at Section 2.3.3.1 of this document. For additional information on the components of HVHF wastewater, *see* Section 2.3.3.4 Pollution from Wastewater Handling and Disposal.

The potential for human exposure to harmful chemicals as result of spills is a cause for concern. The EPA identified 1,606 chemicals associated with the hydraulic fracturing water cycle, including 1,084 chemicals used in hydraulic fracturing fluids, and 599 chemicals detected in produced water (U.S. EPA, 2016a, p. ES-42). The majority of these have not undergone significant toxicological evaluation, a cause for concern in and of itself. Uncertainties in the chemical and toxicological data have constrained attempts to comprehensively assess the potential impacts of hydraulic fracturing on drinking water resources. A 2015 report of the oil and gas industry within the State of California highlighted these limitations:

> The effluent [i.e. produced water from stimulated wells] has not been tested to determine if there is a measurable concentration of hydraulic fracturing chemical constituents. If these chemicals were present, the potential impacts to groundwater, human health, wildlife, and vegetation would be extremely difficult to predict, because there are so many possible chemicals, and the environmental profiles of many of them are unmeasured.

(CCST, 2015a, p.7)

Nevertheless, in U.S. EPA (2016a), the agency stated that it was able to identify chronic oral toxicity values from the selected data sources for 98 of the 1,084 chemicals that were reported to have been used in hydraulic fracturing fluids between 2005 and 2013. Potential human health hazards associated with chronic oral exposure to these chemicals include cancer, immune system effects, changes in body weight, changes in blood chemistry, cardiotoxicity, neurotoxicity, liver and kidney toxicity, and reproductive and developmental toxicity. Of the chemicals most frequently reported to FracFocus 1.0, nine had toxicity values from the selected data sources. Critical effects for these chemicals include kidney/renal toxicity, hepatotoxicity, developmental toxicity (extra cervical ribs), reproductive toxicity, and decreased terminal body weight (U.S. EPA, 2016a, p. ES-43). While acknowledging the uncertainty of measured concentrations of chemicals used in hydraulic fracturing and their potential effect on human health and the environment, CCST reported that:

> Hydroflouric and hydrochloric acids (HF and HCl) are the acids used most often in matrix acidizing and acid fracturing in well development and stimulation and all acid-related activities in oil and gas wells. Both are powerful solvents that are used to dissolve rock formations and can damage mucous

> membrane and tissue through chemical contact, either in liquid or vapor form, leading to skin burns and ulcers, lung damage, and if absorbed through skin, can lead to death.

(CCST, 2015b, p. 690) (internal citation omitted).

Endocrine-disrupting activities are also associated with HVHF wastewater (Kassotis *et al.,* 2018). Co-contaminant effects, such as interactions between hydrocarbons with biocides and/or brine, should be considered when evaluating the risk of HVHF additives and wastewater spills in order to fully understand their potential for transport, degradation and environmental impacts in soil that may have implications for water quality (McLaughlin *et al.,* 2016). Despite industry "best practices" and "zero discharge" designs and despite control regulations and state compliance efforts, small and large volume spills are likely to occur within the Delaware River Basin if the activity were to be permitted. *See,* Mouser, 2020 pp. 7-8 (citing ALL Consulting, 2018) and USGS, 2018, pp. 17, 19; *also see* Patterson *et al.,* 2017 and Maloney *et al.,* 2016 (describing particular spill risks and data needs to assist policy-makers in addressing continued ongoing risk).

Data Gaps/Limitations

As discussed above, the record of hydraulic fracturing-related spills both nationally and within Pennsylvania leaves little doubt that such incidents would also occur in the Delaware River Basin if HVHF were permitted here. Despite the best efforts of researchers to accurately quantify the occurrence and risks associated with such spills, the available data are often insufficient to assess the frequency, magnitude, and short-term and long-term environmental impacts from HVHF spills. Data gaps are a significant limitation that prevents a more thorough understanding of the true impacts of these events. The lack of available data was acknowledged as a major limitation in the EPA's 2016 study on hydraulic fracturing impacts on drinking water, in which the agency noted:

> Data gaps and uncertainties limited EPA's ability to fully assess the potential impacts on drinking water resources both locally and nationally. Generally, comprehensive information on the location of activities in the hydraulic fracturing water cycle is lacking, either because it is not collected, not publicly available, or prohibitively difficult to aggregate. In places where we know activities in the hydraulic fracturing water cycle have occurred, data that could be used to characterize hydraulic fracturing-related chemicals in the environment before, during, and after hydraulic fracturing were scarce. Because of these data gaps and uncertainties, as well as others described in the assessment, it was not possible to fully characterize the severity of impacts, nor was it possible to calculate or estimate the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle.

(U.S. EPA, 2016f). One study of hydraulic fracturing-related water resource impacts in Pennsylvania found that, while the rapid emergence of shale-gas development in the Commonwealth "may have led to relatively few environmental incidents of significant impact compared to wells drilled … the impacts remain difficult to assess due to the lack of transparent and accessible data." (Brantley *et al.,* 2014) The study's conclusion elaborates:

> . . . firm conclusions are hampered by i) the lack of information about location and timing of incidents; ii) the tendency to not release water quality data related to specific incidents due to liability or confidentiality agreements; iii) the sparseness of sample and sensor data for the analytes of interest; iv) the presence of pre-existing water impairments that makes it difficult to determine potential impacts from shale-gas activity; and v) the fact that sensors can malfunction or drift. Although some waterways throughout the state are now monitored, drilling and hydraulic fracturing of the Marcellus has proceeded so rapidly that the sampling and monitoring density is not sufficient to document impacts over either the long term or short term, especially in headwater streams near many well pads.

(Brantley *et al.,* 2014). Other related studies have noted similar data limitations (including with respect to Pennsylvania's oil and gas regulatory program), which must be recognized as a significant factor limiting a thorough and unbiased assessment of the relative safety of hydraulic fracturing (U..S. EPA, 2016a; Konschnik and Dayalu, 2016; NYSDOH, 2014; Abualfaraj *et al.,* 2018).

Further complicating the availability of data regarding the number and severity of hydraulic fracturing-related spills, both nationally and in Pennsylvania, is the manner with which that information is reported, catalogued, and made available to the public. Reporting requirements among the states vary considerably with respect to how and what type of spills must be reported as well as other details such as volume, location, timing, cause of the spill and whether environmental resources (e.g. surface or ground water) have been impacted (Patterson *et al.,* 2017). In examining spill data in their study of four states, Patterson *et al*. also noted about Pennsylvania's oil and natural gas program database that:

> Pennsylvania's 2001 rules required companies to report by telephone to the Department of Environmental Protection any 'reportable release of brine' or the discharge of any substance which would endanger downstream users of water, result in or create a danger of pollution of Pennsylvania waters, or damage property. The report had to include the location and cause of the incident. 'Reportable release of brine' was defined as 'spilling, leaking, emitting, discharging, escaping or disposing' of at least 5 gallons in 24 hours of brine containing more than 10,000 mg/L total dissolved solids (TDS), or of at least 15 gallons of brine with a lower TDS concentration. In October 2016, Pennsylvania's new rules went into effect; these will require written spill reports. Pennsylvania does not have a separate spill data set, therefore spill data for our analysis were pulled from the Department of Environmental Protection's notice of violations (NOV) data-base for UOG (SI, Section B). This necessarily limited the spill data to those where an inspector issued an NOV, possibly leading to an underestimation of the number [of] spills in our analysis.

In their study of spills in Colorado, McLaughlin *et al*. noted that ". . . contaminations [*sic*] caused by spilled fluids in Colorado are solely registered on the basis of detection of select inorganic parameters as well as benzene, toluene, ethylbenzene, and xylenes (BTEX) and total petroleum hydrocarbons (TPH). Other organic chemicals injected during HF are not analyzed. Consequently, spills of fresh, uninjected HF fluids or pure chemical products may remain undetected and unreported." (Mc Laughlin *et al.,* 2016).

Notwithstanding the acknowledged limitations on available information about spills, Patterson *et al.* found 6,648 spills between 2005 and 2014 in the four states studied compared to 457 reported by the EPA in their review of data from eleven states between 2006 and 2012 (Patterson *et al.,* 2017; U.S. EPA, 2015c, p. 1, 24).

Significant Risks to Water Resources from HVHF Spills - Summary

In considering the public comments on its proposed regulations, the Commission has evaluated a decade of scientific and technical data and literature concerning HVHF and related activities. Documented risks from the scientific literature highlight the following:

- the complex chemistry of the fluids injected in large quantities into and returned from natural gas extraction wells in shale formations;
- the carcinogenic and estrogen-disrupting properties of chemicals known to be used in HVHF and to be present in HVHF wastewater;
- the presence of high radioactivity in the produced water recovered from HVHF wells;
- the significant impact that a single spill may have on the health of macroinvertebrates and fish in affected streams;
- the industry's practice of maintaining secrecy about the chemicals used to fracture HVHF wells;
- the geographically dispersed and phased nature of HVHF, which, unlike fixed industrial processes requires the transport of hazardous materials throughout sensitive headwater areas considered to have high water resource values;
- the potential for multiple pathways of exposure to hazardous chemicals due to chemical or produced water spills at or *en route* to (or from) well pads, potentially affecting soils as well as ground and surface waters in the vicinity of each;
- the simultaneous trends identified in recent literature of a decline in the number of wells drilled and an increase in the number of reported spills;
- the virtual certainty that spills covering the full range of volumes and impacts will occur within the Delaware River Basin if HVHF were allowed here.
- Noting the significant number of contaminants associated with HVHF activities, the 2015 Findings Statement issued at the conclusion of New York State's environmental quality review process stated that "[t]hese additives and contaminants could result in significant adverse public health and environmental impacts if spilled or released taking into account potential exposure pathways."

- Additional research published after the publication of EPA's final report on the impacts of HVHF on drinking water resources in December 2016, reinforced earlier findings about the risks to water resources posed by hydraulic fracturing-related spills.

In view of the above, the Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, primarily: in rural areas dependent upon groundwater resources, in sensitive headwater areas considered to have high water resource values, and in areas draining to DRBC Special Protection Waters. Spill events covering the full range of volumes and impacts would inevitably occur, involving harmful pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined. These events would be dispersed over thousands of acres of sensitive water resource features, in a region characterized by extensive geologic faults and fractures.

A decade of experience in other regions has shown that regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills and releases of chemicals and hydraulic fracturing wastewater. Accordingly, the Commission has determined that controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.2.3 Pollution from Fluid Migration

Statement of Concern (SC-33)

Many commenters addressed the potential for fluids (including gases)[30] to contaminate water resources through communication between gas-bearing formations and water resources including freshwater aquifers through natural faults and fractures, through abandoned wells or poorly constructed gas wells, or a combination of both. Commenters on both sides of the question offered support for their views—either that such migration of contaminants is a valid concern or that concerns about migration are unsubstantiated. Representative comments included the following:

Comments Asserting that Concerns About Migration Are Unsubstantiated

1. The risk of fluid migration through natural pathways is low. API submitted a comment to the DRBC in part critiquing EPA's 2016 Final Assessment report (referenced in this Comment and Response Document as "EPA, 2016a") on the proposed regulations. In its critique, API recited the conclusions of two peer-reviewed journal articles—those referenced in this Comment and Response Document as "Flewelling and Sharma, 2014" and "Jackson *et al.,* 2013a"—on which EPA relied for statements to the effect that migration through natural pathways is unlikely. The cited conclusions follow:

[30] A fluid is a substance that flows when exposed to an external pressure. Fluids include both liquids and gases. *See, e.g.,* National Aeronautics and Space Administration (NASA), Phases of Matter (undated).

> [D]ue to the very low permeabilities of shale formations . . . hydraulic fracturing operations are unlikely to generate sufficient pressure to drive fluids into shallow drinking water zones. Some natural conditions could also create an upward hydraulic gradient in the absence of any effects from hydraulic fracturing. However, these natural mechanisms have been found to cause very low flow rates over very long distances, yielding extremely small vertical fluxes in sedimentary basins. These translate to some estimated travel times of 100,000 to 100,000,000 years across a 328 ft (100 m) thick layer with about 0.01 nD (1×10^{-23} m2) permeability.

(EPA, 2016a, p. 6-52 (*citing* Flewelling and Sharma, 2014).

> In deep, low-permeability shale and tight gas settings and where induced fractures are contained within the production zone, flow through the production formation has generally been considered an unlikely pathway for migration into drinking water resources.

(EPA, 2016a, p. 6-51 (*citing,* Jackson *et al.,* 2013d)).

2. A northeastern Pennsylvania landowner and natural gas advocate commented that hydraulic fracturing does not cause gas migration.

Comments Asserting that Concerns About Migration Are Substantiated

3. Commenter Delaware Riverkeeper Network (DRN) (citing Myers, 2012) stated that at least three different substances released by hydraulic fracturing—natural gas (shallow biogenic and deep thermogenic gas), formation brine, and hydraulic fracturing fluid—can reach shallow groundwater or the surface in the DRB and that these contaminants can follow pathways through natural faults and fractures, through abandoned wells or poorly constructed gas wells, or a combination of both.

   DRN (citing Myers, 2012) commented further that formation brine moves under natural forces from deep rock formations to shallow groundwater through natural faults and fractures and that these same pathways are available for potentially toxic hydraulic fracturing fluids and produced water (wastewater) to migrate upward to shallow groundwater under significant pressure due to HVHF.

4. AMC (citing Myers, 2012) commented that the process of injecting fluids into and fracturing the shale causes the potential pollution problem, asserting that contaminated fluids from the hydraulic fracturing process can move from the deep shale to shallower water resources through various pathways including fractures and natural vertical flow, in thousands of years or in less than ten years, thus polluting groundwater.

5. Communication between the shale formation and aquifer layers is claimed to have been the result of hydraulic fracturing activity in Bainbridge, Ohio and Grandview, TX. Commenter DCS noted that the extreme pressures used in hydraulic fracturing create the potential for well casing failures and new connections between underground layers, aquifers and even the surface.

6. Referencing multiple published sources by professional geologists in academia, private practice and public service, a commenter on behalf of DCS and other NGOs asserted that there is no way to control migration of fluids caused by hydraulic fracturing and that scientific evidence of such migration is overwhelming.
7. DRN (citing Myers, 2012) asserted that studies have proven that hydraulic fracturing fluid has reached drinking water wells and that transport has occurred between the gas well and shallow groundwater, adding that the flow of deep brine to the surface and between shale layers is well documented in scientific literature.

RESPONSE (R-33)

The Delaware River Basin Compact confers on the Commission the power to "assume jurisdiction to control future pollution . . . in the waters of the Basin whenever it determines after investigation and a public hearing upon due notice that the effectuation of the comprehensive plan so requires." (Compact § 5.2).

The Comprehensive Plan provides in relevant part:

> The quality of Basin waters, . . . shall be maintained in a safe and satisfactory condition for the following uses: (1) . . . public water supplies after reasonable treatment, except where natural salinity precludes such uses; (2) wildlife, fish and other aquatic life; (3) recreation; . . . (6) such other uses as may be provided by the Comprehensive Plan."

(Water Code, § 3.10.2 B.); and, with respect to the waterbodies classified by the Commission as Special Protection Waters, states in relevant part:

> It is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values.

(*Id.,* § 3.10.3 A.2).

The potential for HVHF to adversely impact the quality of water resources and drinking water supplies in the Basin due to the migration of fluids (including gases) is a complex topic and the subject of ongoing investigation and research. Numerous scientific papers and reports document occurrences and evidence of the presence of gas and/or suspected hydraulic fracturing fluids or produced water in groundwater in different settings and circumstances and evaluate possible pathways for the migration of such fluids. Numerous other studies find no or little evidence of migration of gas or other fluids. The quality of published science is strengthened by the peer review process. Some peer scientists disputing the findings of some studies have formally published their comments, and authors have formally responded.

Comprehensive and authoritative reports that synthesize much of this information are the 2016 EPA final assessment report (U.S. EPA, 2016a) and the New York State DEC Final Supplemental Generic

Environmental Impact Statement (NYSDEC, 2015). The latter two studies conclude that hydraulic fracturing activities can adversely impact and have impacted drinking water resources through fluid migration.

In addition, a public health review of hydraulic fracturing conducted by the New York State Department of Health concluded that:

> . . . there are significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health.

(NYSDOH, 2014). The EPA and New York State reports are described in greater detail in Section 2.3.1., Basis and Background Documents.

The subsurface migration of gas and/or other fluids requires a pathway, induced or natural, with high enough permeability and hydraulic gradient to drive fluid movement at relevant rates. Pathways can be related to (1) inadequate or degraded well casing or cement, or (2) induced fractures and/or other features within subsurface formations (U.S. EPA, 2016a, p. 6-3). EPA identifies four classes of potential subsurface migration pathways for HVHF gas, other fluids, and formation water that may contribute to fluid migration or communication between zones as a consequence of HVHF:

- Migration out of the production zone through pore space in the rock;
- Migration due to fracture overgrowth out of the production zone;
- Migration via fractures intersecting offset wells or other artificial structures; and
- Migration via fractures intersecting other geologic features, such as permeable faults or pre-existing natural fractures.

See, U.S. EPA, 2016a, p. 6-4. PADEP Oil and Gas Bureau staff advised the Commission that they have not observed any instances of migration from the target formation through natural pathways as a result of HVHF in Pennsylvania.

The scientific research to date on whether as a result of HVHF gas and other fluids are likely to migrate through natural pathways between a gas production zone and shallow freshwater resources within a time horizon on the order of decades (and not millenia) is summarized below. The questions of whether HVHF may mobilize fluids within non-target ("intermediate") zones or induce fluid migration through artificial pathways such as the wellbore are separate questions that are discussed later in this section.

Some published reports assessing environmental impacts of hydraulic fracturing have concluded that aquifer contamination by the upwelling of fluids from production zones through natural fractures is not supported by data from the field and is highly unlikely (Soeder and Kent, 2018; TAMEST, 2017, p. 122). A wide range of hypothetical modelling analyses of fluid migration suggests that migration of gas or other fluids is unlikely in the absence of an existing, relatively permeable fault or other structural feature through which migration might occur. Disagreements among scientists who use models to help answer the question are sometimes aired directly in the peer-reviewed literature. These discussions help to clarify important nuances of the science and can provide focus for management decisions.

An example is the discussion of a paper by Myers (Myers, 2012), funded by the Park Foundation and Catskill Mountainkeeper, which concluded that migration from a gas production zone to drinking water aquifers through fault zones could occur through conductive faults or fracture zones within as little as a few years (as noted in numbered comment 5 above, submitted by the Adirondack Mountain Club). The Myers analysis and findings were formally disputed by several scientists (*see,* Saiers and Barth, 2012; Cohen *et al.,* 2013; Carter *et al.,* 2013; Engelder *et al.,* 2014). A paper developed in response to this discussion by members of the consulting firm Gradient was funded by Haliburton Energy Services, Inc. (Flewelling and Sharma, 2014). The paper presented information and analysis to demonstrate constraints on upward migration of fluids from black shales in typical sedimentary basin settings, such as those of the Marcellus, the Barnett (TX), the Bakken (ND/MT), the Niobrara (CO/WY), and the Eagle Ford (TX) black shales. The authors concluded that fluid migration is greatly constrained by very low vertical permeabilities, limited fracturing within the target formation, and low flow rates that are often greater than 10^6 years. They ultimately concluded that this mode of migration is not possible. A modeling analysis by Gassiat *et al.,* which aimed to address shortcomings of the Myers analysis, concluded to the contrary, that under specific conditions, contaminant migration to an aquifer would occur in less than 1,000 years, and that hydraulic fracturing should not be conducted near potentially conductive faults (Gassiat *et al.,* 2013). The Gassiat study was funded by the Natural Sciences and Engineering Research Council of Canada and the Quebec Research Fund. In a published comment funded by Haliburton Energy Services, Inc., Flewlling and Sharma criticized the Gassiat study as unrealistic (Flewelling and Sharma, 2015). Other researchers have found that, as the assumed vertical separation between the targeted formation and aquifers decreases, or as the vertical permeability increases due to the presence of joints, faults, or other higher permeability zones, the likelihood of upward migration of fluids increases (Birdsell, 2019; Birdsell *et al.,* 2015; Warner *et al.,* 2012b).

Results of an important modelling study conducted by the Lawrence Berkeley National Laboratory ("LBNL") and funded by the EPA were published in 2015 (Reagan *et al.,* 2015). Part of the Congressional directive (P.L. 111-88) for EPA to ". . . carry out a study of the relationship between hydraulic fracturing and drinking water . . . ," this study aimed to resolve at least part of the migration question by providing improved modelling to elucidate possible transport mechanisms. The objective of the LBNL study was described this way:

> . . . by identifying the processes that enhance or mitigate flow and transport out of TG [tight-sand and gas shale] reservoirs, and by examining a range of geological parameters and production techniques, the envelope of potential system behavior (and of possible hazards) can be better defined. This may then inform well design, fracturing operations, production strategies, monitoring studies, and the scope of future modelling work.

(Reagan *et al.,* 2015, p. 2544).

The Reagan study describes potential short-term migration (occurring over weeks to months) of gas and water between a shale or tight gas formation and a shallower groundwater unit, assuming a pre-existing permeable pathway between the two formations. The study results identified the main factors affecting transport of gas to aquifers as: (1) production regime (whether the production well is producing or is shut-in); (2) the permeability of the connecting feature; and, less so, (3) the vertical separation between the production formation and the aquifer.

Investigators have used a variety of approaches to determine or infer the presence or absence of geologic structures with relatively high permeability that could potentially provide natural pathways for subsurface migration of HVHF gas or fluids to shallow groundwater. Results of these studies are mixed. In some cases, migration of fluids is identified and attributed to hydraulic fracturing activity, but the pathway of migration is not identified.

DRBC asked the USGS to "characterize the likelihood and potential severity of contamination of drinking water resources resulting from the migration of contaminants from target formations via natural pathways, as influenced by high volume hydraulic fracturing" within the Delaware River Basin. The USGS highlighted the risk that hydraulic fracturing might result in fluid migration into the margins of adjacent formations with higher permeability than the Marcellus/Utica, but found the risk of movement from these regions to the surface to be a low-probability scenario based on the literature and understanding to date. (USGS, 2018, pp. 14, 19). Regarding natural pathways from target formations to shallow aquifers, the USGS stated:

> Based on our knowledge, experience, and review of the relevant literature and our own research, the USGS believes that it is unlikely that there are exceptional subsurface natural pathways present in the DRB that would offer an undue or unusual risk of accelerated release of natural gas, fracking fluids, or formation waters to the environment or to shallow aquifers following hydraulic fracking of the Marcellus Shale or Utica Shale Formations. However, the risks from activities associated with the fracking and the subsequent resource development are not inconsequential and monitoring and oversight of such activities are essential.

(USGS, 2018, p. 19).

The Commission agrees that the research to date suggests gas, hydraulic fracturing fluids, and formation brine are unlikely to flow through natural pathways from the target (production) zone and adjacent areas to shallow aquifers. However, DRBC's review of the peer-reviewed research on migration from the target formation also indicates that certain conditions are typically assumed (*see, e.g.,* Flewelling and Sharma, 2014; Zoback and Arent, 2014; Jackson *et al.,* 2013a; NETL, 2013, p. 61). These conditions include: (1) a "typical" geologic setting in which the low-permeability natural gas production formation is deeply buried (2-3 km or more), flat-lying or gently dipping, and is relatively undisturbed, as are many major gas plays in the United States; and (2) where an HVHF gas well is constructed properly, the mechanical integrity of the well is maintained, and zonal isolation within the target geological formation is preserved. Under these conditions, there is a large vertical separation between the production formation and freshwater aquifers; the production formation and intervening formations have extremely low natural permeability; and well construction and maintenance are successful in achieving and maintaining effective zonal isolation. The two studies cited by API for the proposition that migration is unlikely refer to conditions such as these. (Additional field studies that demonstrated the effectiveness of vertical separation in preventing fluid migration were conducted in Green County, PA (Hammack *et al.,* 2014), and Susquehanna County, PA (Barth-Natfilan *et al.,* 2018), and are discussed in greater detail in Section 2.3.3.3, Groundwater.) The Commission agrees with API's comment (numbered comment 1 above) that the risk of gas or fluid migration through natural pathways is low when the conditions described above are present. In other circumstances, however, the probability of migration may be substantially higher, especially in cases in which well integrity is compromised (Jackson *et al.,* 2013b; U.S. EPA, 2016a, p.10-13). The geologic setting in northeastern Pennsylvania may be more prone to fluid migration and impacts to water resources than are shale-gas settings in central and western Pennsylvania and elsewhere (USGS, 2018, p. 13; Woda *et al.,* 2018; Soeder, 2017).

If the likelihood of migration via natural pathways from the target formation to shallow aquifers and streams is limited under assumed conditions, the evidence is strong that HVHF can result in the migration of fluids—whether from the target formation or intermediate zones—through *artificial* pathways or a combination of natural and artificial pathways into shallow water-bearing zones. As explained below, fluid is more likely to migrate through poorly constructed or abandoned gas wells than solely through natural faults and fractures (Zoback and Arent, 2014; Jackson *et al.,* 2013a), and gas is more likely than liquids to migrate in this manner. PADEP adopted regulations in 2016 to address communication with offset wells (including abandoned wells). This has no doubt reduced risk in areas where abandoned wells are prevalent, a condition not believed to exist in the Delaware River Basin. The Commonwealth also significantly upgraded its casing and cementing/well construction and operation regulations in 2011 to address issues associated with poorly constructed wells (*see* Appendix-4), but incidents of fluid migration continue to occur. Migration pathways in some areas may be the result of inadequate well integrity in combination with geologic factors, including those of intermediate, non-target (but often gas bearing) formations, as explained below.

The Commission rejects the assertion (see numbered comment 2 above) that high volume hydraulic fracturing *does not cause* gas migration. Regulatory documents and the literature are replete with examples to the contrary, including documented cases such as those in Bainbridge, OH (22 private domestic wells and one public water supply well affected) (ODNR, 2008, p. 6); Dimock, PA (18 private domestic wells affected) (PADEP, 2009; PADEP, 2010); other areas in Susquehanna and Bradford Counties, PA (9 private domestic wells affected) (U.S. EPA, 2015d, p. 109); and many other locations in Pennsylvania (PADEP, 2019d), including instances in which PADEP issued a Consent Assessment of Civil Penalty or Consent Order and Agreement. The latter include instances in: Lycoming County (PADEP, 2020a); Bradford and Sullivan Counties (PADEP, 2018c); Nicholson Township, Wyoming County (PADEP, 2017a), Forks Township and Elkland Township, Sullivan County (PADEP, 2016a); West Burlington Township, Bradford County (PADEP, 2017b); Leroy Township, Bradford County (PADEP, 2015b); Lenox Township, Susquehanna County (PADEP, 2016f); and elsewhere, as documented by the EPA (U.S. EPA, 2016a, pp. 6-23 – 6-25).

The Commission has confirmed that the Bainbridge, OH incident (cited in numbered comment 6 above) was caused by communication between the production formation and the aquifer. The communication pathway was within the gas well borehole and resulted from a defective cement job during well construction, according to the Ohio Department of Natural Resources (ODNR, 2008, p. 46). Other than a news article provided by commenter DCS (Gorman, 2008), little information is available regarding the 2007 incident in Grandview, TX. Although the specific migration pathways in incidents such as these are often poorly understood, the respective investigating authorities concluded that hydraulic fracturing activities caused the migration and resulting ground water contamination.

Key issues that emerge from this discussion regarding natural migration pathways are (1) vertical separation distance between the production zone and the deepest drinking water aquifer; and (2) the likelihood of the presence of zones or features of higher vertical permeability, such as joints, faults, or fractures, that could provide a preferential pathway for migration. The focus of the discussion as it relates to numbered comment 5 above, therefore, is the geologic setting of the Delaware River Basin.

Research focused on northeastern Pennsylvania and nearby parts of New York has demonstrated that local geology can help explain why fluid migration to aquifers occasionally occurs. The geologic setting in northeastern Pennsylvania and in the New York part of the Delaware River Basin is not "typical" as described above and may be more prone to potential migration and impacts to water supplies than shale-gas areas in central and western Pennsylvania and elsewhere. Several studies and reports provide evidence supporting this hypothesis. In northeastern Pennsylvania and adjoining areas of New York within the Basin, the Paleozoic Formations were subjected to tectonic forces and deformation that generated a marked change in their structural configuration. The formations have been extensively folded, faulted, and eroded through geologic time. As a result, the Marcellus Shale dips upward steeply and crops out at the earth's surface in places near the Delaware River. A consequence of this structural change and the associated low-grade metamorphism is the presence of rock cleavage, a greater tendency for fracturing and higher permeability, and therefore greater risk for fluid transport to adjacent formations and through intersected bedding planes, fractures, geologic faults, or other features such as solution cavities in overlying strata (USGS, 2018, p. 13-14; USGS, 2012, p. 9-10). There may be a higher likelihood in the DRB of natural pathways in shallower formations, which would increase the likelihood that inadequate HVHF well integrity will lead to contamination of aquifers.

A 2018 study led by Penn State showed that local geologic conditions similar to those in some parts of the Delaware River Basin may explain gas migration into private drinking water wells and a stream near hydraulically fractured natural gas production wells in Lycoming County, Pennsylvania (in the West Branch Susquehanna sub-basin). These results indicate that migration may be more likely in areas where the Marcellus Shale is situated at a relatively shallow depth, dips significantly, and is more fractured than in other areas, as in portions of the Delaware River Basin (Woda *et al.,* 2018).

A 2017 study led by the Lamont-Dougherty Earth Observatory at Columbia University examined the association of groundwater constituents with topography and proximity to unconventional gas wells in northeastern Pennsylvania (Yan, *et al.,* 2017). Results indicated that calcium, chloride and sulfate (Ca, Cl, and SO4) levels are higher in groundwater near unconventional gas wells, especially in valley settings. The study provides additional evidence that unconventional gas development may be impacting groundwater.

A study conducted by the USGS in 2017 (and published in 2019) examined chemical, isotopic, and groundwater-age tracer data in upland groundwater in northeastern Pennsylvania (McMahon *et al.,* 2019). The study explored relations between chemical constituents and proximity to unconventional gas wells and mapped faults and fold axes that might act as pathways for migration of fluids. In contrast with the Lamont-Dougherty study (Yan *et al.,* 2017), the USGS research found no correlation between chloride and distance to the nearest unconventional gas well. The USGS researchers stated that this difference in results might be attributable to the smaller number of wells sampled (50) in the USGS study, in comparison with the more that 1,700 wells sampled in the Lamont-Dougherty study. The USGS data suggested that thermogenic methane detected in one well located 0.37 km (0.23 mi) from an unconventional gas well is from a relatively shallow source (Catskill/Lock Haven Formations) that "appears to have been mobilized by shale-gas production activities." Data for another well located less than 1 km from an unconventional gas well suggested that thermogenic methane in groundwater at that location is associated with natural migration processes, and perhaps marks a hotspot associated with a geologic structure known as the Wilmot anticlinal axis. Notwithstanding the lack of correlation between chloride and proximity to HVHF wells, these results suggest that relatively permeable connections may exist between gas reservoirs and upland groundwater in the region.

Studies of methane in groundwater in the Marcellus region, including some by the USGS, suggest the possible presence of permeable geologic features that facilitate gas migration. A 2013 USGS study of methane in groundwater of south-central New York State revealed evidence of a possible migration pathway from underlying formations. Methane in valley wells was predominantly thermogenic in origin, likely as a result of close vertical proximity to underlying methane-bearing saline groundwater and brine, and possibly as a result of enhanced bedrock fracture permeability beneath valleys that provides an avenue for upward gas migration (Heisig and Scott, 2013). Another approach to identifying permeable geologic features is geospatial analysis of methane concentrations in groundwater from private wells in relation to mapped geologic features. Methane concentrations measured in shallow private water wells in Bradford County, PA were found to increase with proximity to faults and also to conventional gas wells, though not to unconventional wells. This result demonstrates that if a well intersects faults at a depth where it is uncased or uncemented, it may provide a pathway for migration of gas from methane-bearing formations. Data mining was used to map hotspots where methane concentrations significantly correlate with distance to faults and gas wells. Near the hotspots, 3 out of 132 shale-gas wells (approximately 2 percent) and 4 out of 15 conventional wells (27 percent) intersect faults at depths where they are reported to be uncased or uncemented (Li *et al.,* 2016b).

Other studies have examined chemical components of Appalachian basin brines ("ABB") in groundwater to determine the presence or absence of natural pathways of brine migration that could potentially also conduct HVHF gas or fluids to shallow groundwater. Several researchers have presented geochemical evidence of natural migration of Marcellus Formation brine to shallow aquifers in northeastern Pennsylvania within or near the Delaware River Basin (Wen *et al.,* 2018; Llewellyn, 2014; Warner *et al.,* 2012b). They theorize that this migration could possibly be a result of natural pathways that developed in response to tectonic activity that produced vertical joints across formations, alone or in combination with the effect of glaciation, which increased fracture density and permeability. When glaciers retreated from northeast Pennsylvania, the removal of the weight of the glaciers allowed the land mass to rise, or rebound, causing stresses in the subsurface and producing more fracturing (Warner *et al.,* 2012b). However, the effects of glacial retreat most likely impact only the shallow rocks and not deeper gas shales (Charpentier *et al.*, 1982). The 2012 study led by Penn State University presents geochemical evidence from northeastern Pennsylvania showing that natural pathways unrelated to drilling activities exist in some locations between deep underlying formations and shallow drinking water aquifers. Integration of inorganic chemical data and isotopic ratios in shallow groundwater samples and northern ABB samples suggests that mixing of shallow groundwater and deep formation brine causes groundwater salinization in some locations. The strong geochemical fingerprint in the salinized groundwater sampled from the Alluvium, Catskill, and Lock Haven aquifers suggests possible migration of Marcellus brine through naturally occurring pathways. The presence of salinized groundwater further suggests the presence of conductive pathways and specific geostructural and/or hydrodynamic regimes in northeastern Pennsylvania that may increase the risk of shallow groundwater contamination, particularly by stray gases, because of natural hydraulic connections to deeper formations (Warner *et al.,* 2012b). The observed evidence and unique structural characteristics of the region suggest the possibility that the Marcellus Shale could be more vulnerable to fluid migration from HVHF activity in the Delaware River Basin than in other areas of Pennsylvania. This interpretation of geochemical evidence is controversial and has been the subject of a formal dispute among Penn State University researchers in the literature (Engelder, 2012; Warner *et al.,* 2012a).

Another study in Susquehanna County, Pennsylvania, published in 2014, utilized a geospatial analysis of geologic features, groundwater quality data, and ABB data to assess pre-gas-drilling groundwater salinization sources. The study concluded that ABB has migrated naturally and preferentially to shallow aquifers along an inferred normal fault and certain topographic lineaments. The natural presence of ABB-impacted shallow groundwater shows the existence of vertical migration pathways that may result in gas-drilling impacts (Llewellyn, 2014).

Some studies of methane in groundwater in the Marcellus region reached contrary conclusions about methane migration. A 2013 study of methane sources in groundwater by employees of GSI Environmental, Incorporated and Cabot Oil and Gas Corporation concluded that methane concentrations in Susquehanna County water wells can be explained without the migration of Marcellus Shale gas through fractures (Molofsky *et al.,* 2013).

Without citing any specific studies or results, numbered comments 7 and 8 above allude to studies that "have proven" the occurrence of fluid transport between gas wells and shallow groundwater and the existence of "overwhelming scientific evidence" of such transport. DRBC has carefully reviewed the literature and agrees that some studies present compelling evidence that hydraulic fracturing fluids have migrated to drinking water sources. Although the findings of these studies remain controversial, they provide strong evidence that DRBC cannot responsibly ignore. The study by Llewellyn *et al*. (2015) is a particularly strong example. Funded by Leco Corporation, Restek Corporation, the National Science Foundation, and Penn State University, the authors (one of whom also provided litigation support and environmental consulting services for impacted households) investigated the source of contamination of several private residential wells in Bradford County, PA, near gas wells that had been cited for allowing natural gas to enter aquifers. The wells had defective well construction that had been remediated with cement squeezes and plugs under a PADEP consent order and agreement. The study approach used multiple lines of evidence, including: (1) time series analyses of natural gas and organic and inorganic compound concentrations; (2) comparisons of natural gas isotopic compositions between gas well annular gas and groundwater; (3) assessments of gas well construction; (4) chronology of events; (5) hydrogeologic characterization; and (6) geospatial relationships. The study used a coupled gas chromatography/mass spectrometry analytical method that identified similar unresolved complex mixtures of organic compounds in the affected aquifer and in flowback from other Marcellus Shale gas wells. Using results from these six lines of evidence, the researchers concluded that stray gas and drilling or hydraulic fracturing fluids may have flowed vertically along gas well boreholes and then approximately 1-3 kilometers (0.62 – 1.9 miles) along shallow and intermediate depth fractures to the aquifer supplying water to the impacted domestic water supply wells. Wastewater from a reported pit leak at the nearest gas well pad may have been a source of the hydraulic fracturing fluids. The analytical method used in the study might have conclusively fingerprinted the specific contaminant source, but samples from the drilling, pit and HVHF fluid at the five suspect well pads were not available to the researchers.

In a report commenting on EPA's 2015 draft assessment, the environmental and risk sciences consultant Gradient on behalf of its client Haliburton Energy Services, Inc. criticized the Llewellyn study (Llewellyn *et al*. (2015) for what Gradient described as fundamental flaws, including failure to characterize undifferentiated hydrocarbons (also referred to as unresolved complex mixtures, or UCMs) in the drilling or hydraulic fracturing fluids that were used to construct and stimulate the gas wells (Gradient, 2015, p. 20). In other words, the industry consultant criticized the study for not including sampling that the industry refused to allow. The Gradient report presented no alternative hypothesis to explain why, following HVHF activity in the vicinity, the previously potable water supplies became contaminated by gas, a foaming agent, and chemical signatures similar to that of flowback from hydraulic fracturing in the Marcellus Shale in other areas. The Llewellyn study provides persuasive evidence of fluid migration from HVHF activity to groundwater supplies. The study reinforces that incidents of contamination are typically tied to well integrity impairments and not out-of-zone fracture growth to the base of fresh groundwater.

Numbered comment 6 asserts that there is no way to control fluid migration caused by hydraulic fracturing. The industry has developed techniques for modelling fracture propagation, calculating stimulated fracture height and width, and planning and limiting the extent of hydraulically-induced fractures to within a target zone (Veatch *et al.,* 2017). Industry standards and best practices have been developed to help ensure that wells and fracture networks are designed and constructed to achieve and maintain zonal isolation (*see* API, 2019). However, in areas where target formations are thin, out-of-zone[31] fracture growth may be more likely. Industry experience indicates that out-of-zone fracturing may be common in the Bakken Shale in the northern U.S. and Canada (U.S. EPA, 2016a, p. 6-55), but there is no evidence that out-of-zone fracture propagation to shallow groundwater has occurred from deep (>1000m or >3000 ft) shale gas reservoirs (Jackson *et al.,* 2013a). As described previously, migration of fluids in certain geologic settings and where wells are properly designed and constructed is unlikely; however fluid migration may be more likely in less favorable geologic settings, in situations where well integrity is compromised, or both. It is possible to control fluid migration, but zonal isolation is not always achieved and maintained.

Regarding the natural flow of deep brine and gas to the shallow groundwater and the surface (noted in numbered comments 3 and 7 above), several studies present geochemical evidence of such natural migration of formation brines and gas and present different hypotheses for migration pathways. The differences among these hypotheses result in uncertainty about the existence of preferential pathways that might create greater risks for fluid migration from HVHF activities. One study in Susquehanna County, PA, conducted and funded by an industry consultant and Cabot Oil and Gas Corporation, concluded that elevated concentrations of various inorganic constituents in groundwater were

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[31] Out-of-zone fracturing refers to fractures extending out of the intended production zone into another formation, or into an unintended zone within the same formation.

the result of long residence times and aquifer-rock interactions associated with deeper groundwater flow within aquifer strata, and that zones of greater fracture density are pathways for the migration of naturally occurring gas and saline water from saline groundwater zones within aquifer strata (Molofsky *et al.,* 2013). A subsequent study by Syracuse University and industry employees, funded by Chesapeake Energy Corporation, utilized a large data set for the entire Appalachian basin and reached a similar conclusion that groundwater discharging along slopes and in valleys travels along longer flow paths and commonly intersects saline zones at the base of the aquifer (Siegel *et al.,* 2016). These studies concluded that the presence of methane could be explained without the migration of Marcellus Shale gas through fractures.

In contrast with these results, a study in south-central New York State by USGS concluded that enhanced bedrock fracture permeability, including faults extending through the entire sedimentary sequence beneath valleys, could provide a pathway for upward gas migration (Heisig and Scott, 2013). Other studies conducted in northeastern Pennsylvania (Warner *et al.,* 2012b; Llewellyn, 2014) and southern New York (Kreuzer *et al.,* 2018) present geochemical evidence for natural migration of formation brines to shallow aquifers through natural faults or other conductive pathways that exist in some locations between deep shale formations and shallow aquifers. Results suggest that areas where this preferential migration occurs could be at greater risk for contamination resulting from hydraulic fracturing activity because of a pre-existing network of pathways that has enhanced hydraulic connectivity between deeper geological formations and shallow aquifers. Other evidence of fluid migration is presented in Section 2.3.3.3, Groundwater.

In conclusion, the DRBC finds on the basis of the peer-reviewed literature to date, that the probability of fluid migration is low in "typical" unglaciated, tectonically tranquil shale-gas settings where the target formation is deep, flat-lying, and characterized by low permeability, and in which gas wells are constructed and maintained properly. However, the weight of the evidence in the view of the DRBC also shows that the probability of fluid migration as a result of HVHF may be substantially higher in other settings, including in northeastern Pennsylvania, where numerous documented incidents of impacts to water resources have occurred in connection with natural gas extraction, either where wells are not constructed and maintained properly and/ or where geologic characteristics that are present in this region contribute to elevated risk of fluid migration through permeable features in relatively shallow formations.

Statement of Concern (SC-34)

Some commenters remarked on the potential for migration pathways to be created as a result of seismicity induced by hydraulic fracturing. Statements on both sides of this issue are paraphrased or quoted as follows:

1. Fracking activity itself can cause earthquakes, as has been seen across the United States and in Canada, and "as close to the Delaware River Basin as Lawrence County, Pennsylvania."
2. There are many pathways for contamination to reach shallow groundwater from either the well bore or the targeted shale. The pathways include fractures and faults, faulty wellbores, and seismic activity. Earthquakes associated with increased fracking would likely cause additional gas to be released.

3. Hydraulic fracturing is safe, does not contaminate drinking water, cause earthquakes, or otherwise endanger the environment.

Response (R-34)

According to William Ellsworth of the United States Geological Survey's Earthquake Science Center, a range of human activities are capable of inducing earthquakes, including impoundment of water in reservoirs, surface and underground mining, withdrawal of fluids from the subsurface, and injection of fluids into underground formations (Ellsworth, 2013). The primary cause of the increase in induced earthquakes, according to the USGS is not hydraulic fracturing but the injection of waste fluids from oil and gas production into underground disposal wells (Rubinstein and Mahani, 2015). Some earthquakes have been induced by hydraulic fracturing in various regions in North America, China, and the United Kingdom (Eyre *et al.,* 2019), but not in northeastern Pennsylvania. In British Columbia, more than 200 seismic events, including events greater than 2.0 M,[32] were caused by fluid injection during hydraulic fracturing in proximity to pre-existing faults in the Horn River Basin (BCOGC, 2012). As hydraulic fracturing activity in the region expanded, both the number and magnitude of induced seismicity events increased. A study led by the U.S. Geological Survey showed that in Oklahoma, more than 200 hydraulic fracturing wells were correlated with more than 700 earthquakes with M ≥ 2.0, primarily in the SCOOP/STACK plays (an oil-producing geographic area in Oklahoma) (Skoumal *et al.,* 2018b). The observations of seismicity induced by hydraulic fracturing in the Appalachian Basin are concentrated in a narrow north-south corridor in eastern Ohio and central West Virginia (Brudzinski and Kozlowska, 2019). HF-induced seismicity has also occurred near this corridor in Lawrence County, PA (northwest of Pittsburgh) (Frazier, 2017b). One of the HF-induced events, a M 3.7 earthquake in Ohio, was widely felt in the rural epicenter area, and the USGS received over 100 reports from people who felt it (Brudzinski and Kozlowska, 2019). The higher prevalence of HF-induced seismicity in this Appalachian Basin corridor is due to targeting of the Utica-Point Pleasant formation, which is in closer vertical proximity to basement rocks in this corridor than is the Marcellus formation in northeastern Pennsylvania (Brudzinski and Kozlowska, 2019). Underground injection of wastewater and hydraulic fracturing activity in strata lying less than one kilometer above basement rock is hypothesized by the U.S. Geological Survey to be more likely to result in induced seismicity (Skoumal *et al.,* 2018a). This hypothesis may explain why induced seismicity has not occurred as a result of HVHF activity in northeast Pennsylvania where the Marcellus Shale is situated more than a kilometer above basement rock.

The potential for fault activation and flow path creation under conditions similar to those of the Marcellus Shale play was studied by Lawrence Berkeley National Laboratory using numerical simulations. Results of the study indicated that:

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[32] "M" denotes the moment magnitude scale of earthquake magnitude.

> the possibility of hydraulically induced fractures at great depth (thousands of meters) causing activation of faults and creation of a new flow path that can reach shallow groundwater resources (or even the surface) is remote.

(Rutqvist *et al.,* 2013). Given the results of studies described above, and the absence of HF-induced seismicity in northeast Pennsylvania despite a high intensity of HVHF activity, the likelihood of induced seismicity in the Delaware River Basin as a result of development of Marcellus Shale gas, and the subsequent migration of gas or fluids through pathways generated by HV-induced seismicity, appears to be low. In the Delaware River Basin, the vertical separation between the Utica-Point Pleasant shale and basement rock may not be known in some areas (Berg *et al.,* 1993), and so the likelihood of induced seismicity in the Delaware River Basin as a result of development of Utica-Point Pleasant shale gas may be less certain.

Statement of Concern (SC-35)

Numerous comments were submitted about the potential for HVHF impacts to water resources resulting from gas well integrity issues. Commenters noted many reasons why they consider the various well-integrity concerns to be either substantiated or unsubstantiated. Statements on both sides of the question are paraphrased or quoted as follows:

Comments Asserting that Concerns About Well Integrity Are Unsubstantiated

1. API asserts that since 1924, it has led in the establishment, maintenance, and dissemination of hundreds of standards to ensure the safe and sustainable development of oil and natural gas in the U.S. and across the world.

2. API further states that each API standard is reviewed at least every five years to maintain its integrity; that API's standards represent industry safety practices based on the best available science and research; and that the latter is one reason API's standards are widely cited, and often incorporated, in federal and state regulations.

3. API asserts that as its standards are implemented and their effects measured, they add to the body of knowledge of industry best practices and lessons learned, and deliver significant improvements to system integrity, reliability, and integrated safety.

4. Citing its own standards, API notes, "The industry has developed techniques for improving well drilling, cementing, and casing to protect freshwater sources, restrict fluids to the intended zone, and enable efficient hydrocarbon production. The primary means of ensuring that underground sources of drinking water are protected is by carefully casing the well with a steel pipe and cementing it into place to create a tight seal." (API, Undated).

5. A northeastern Pennsylvania landowner and natural gas advocate asserted that risks due to declining well integrity do not increase over time, as pressures [within the cased well] decrease over time.

6. According to MSC, "With an environmental compliance rate of nearly 97% , operating under some of the most stringent and rigorous environmental standards in the nation,

Pennsylvania's unconventional shale gas industry has a demonstrated track record of operating in a manner that protects our shared environment." (MSC, 2018, p. 3 (ltr.)(citation omitted)).

7. In its critique of the 2016 EPA assessment report, Halliburton Energy Services, Inc. commented that impacts associated with failure of well casing or cement generally involve methane, not hydraulic fracturing fluids, reflecting the fact that methane is more mobile in the subsurface and hydraulic fracturing fluids are not likely to migrate upward to reach drinking water aquifers even when wellbore integrity is compromised.

8. API offered in its comments a prediction that 3.63 release events would occur in the Delaware River Basin each year, assuming the development of 40 wells annually as projected by ALL Consulting, LLC. API states that its prediction is based on statistics for release incidents (including spills, leaks, well integrity and erosion control events) in Susquehanna County, Pennsylvania during 2013-2017, which were reported at 9.09 percent of wells drilled during that period. API further opines that the probability that even one of such events would result in contaminants reaching waters of the Commonwealth was less than 0.5 percent (ALL Consulting, 2018).

9. In its critique of the 2016 EPA assessment report, Halliburton Energy Services, Inc. commented that "there is no evidence of the migration of fracturing fluids into drinking water resources via any subsurface pathway." (Gradient, 2015, p. 2).

Comments Asserting that Well Integrity Concerns Are Substantiated

10. There is concern over water contamination stemming from well integrity failures due to aging cement/grout and the pressures of hydraulic fracturing itself. The underground migration of methane and a plethora of hydraulic fracturing chemicals associated with faulty well construction may have impacts on drinking water.

11. Well casings, cementing, and cement plugs are not regulated to protect aquifers and will lead to pollution, either in the short term or as they degrade.

12. Cement shrinkage, debonding, and failure can result from a variety of causes.

13. Current state-of-the-art cement materials used in well completion, plugging and abandonment operations do not have a documented long-term history of durability.

14. It is not a matter of "if" these hydraulic fracturing wells will fail, but "when."

15. The implications of short-term cement failure on long-term aquifer water quality protection are extremely significant.

16. Problems with the integrity of well cement are well known in oil and gas fields. Fractured shales of the Appalachian Basin may present problems when cementing wells. The 2006 report by Newhall states: "These problems include cement dehydration due to excessive fluid loss or formation "breakdown," in which whole cement slurry is lost to a created hydraulic

fracture. When this situation is encountered, it can be difficult to achieve proper cement tops and cement bond quality can be poor." (Newhall, 2006)

17. The number of hydraulic unconventional well encasements that have failed is over six percent. Meanwhile, a Cornell study forecasts an even higher percentage: four in ten unconventional wells will fail in Northeast Pennsylvania.

18. The life of the cement and steel casings is less than the life of an aquifer – we are digging the grave for our freshwater for future generations with a failure rate of 5-10 percent.

19. The large number of incidents of pollution, methane gas migration, blowouts and other problems throughout Pennsylvania is well documented by PADEP.

Response (R-35)

The industry, regulators, and the scientific community have gone to great lengths to ensure gas well integrity and zonal isolation. However, despite these many efforts, including significant improvements over the past decade, the Commission deems the commenters' concerns about well integrity and zonal isolation to be well-founded. The Commission's assessment is based on an integrated view of the technical challenges of properly developing an unconventional gas well, the technical factors that can contribute to integrity failure, and the limits of institutional measures intended to help prevent integrity failure. A common theme across these factors is the underlying uncertainty that exists about short- and long-term well integrity. In DRBC's assessment, the aggregate risks of failure of well integrity over the entire life cycle of a well are substantial and pose threats of migration of gas and other fluids into shallow groundwater and surface water.

Developing a properly constructed unconventional gas well is a complex process, and achieving and maintaining zonal isolation has long been a central challenge. The Commission agrees with numbered comment 16 above that problems with the integrity of well cement are commonly recognized. Although the cited 2006 Newhall study preceded the adoption of well construction regulations by PADEP in 2011 (see Appendix-4), industry literature evidences abundant awareness of the persisting problem, which is also discussed in detail by the 2016 EPA assessment report (U.S. EPA, 2016a, Chapter 6). Some key examples from industry sources are presented below.

A 2017 textbook on hydraulic fracturing written by leaders in the petroleum industry concisely states the importance of the issue: "The key to protecting freshwater aquifers is wellbore integrity." (Veatch *et al.,* 2017).

Industry has acknowledged that uncontrolled migration of hydrocarbons to the surface has been a challenge since the earliest gas wells were drilled; at one point in time (2003) 43 percent of wells in the Gulf of Mexico had reported leakage (Brufatto *et al.,* 2003). Even with technological and chemical improvements in cement and cement placement technology, industry sources and peer-reviewed literature indicate that losses of wellbore integrity occur regularly, if infrequently.

The definition of "well integrity" is important in this discussion, as different definitions are sometimes used, making comparisons among well-integrity studies difficult. According to the Groundwater Protection Council,

> Well integrity, from the perspective of water protection, means the structurally sound construction of a well, including competent pressure seals and operational controls that effectively prevent uncontrolled fluid releases or migration of annular fluids into protected groundwater *throughout the life cycle of a well*.

(GWPC, 2017, p. 43)(emphasis added). The last seven words of this definition are critical, as some studies do not consider the entire life cycle of the well. Among the latter is the 2013 study by King and King, which examines the frequency of integrity failures during well operation, but not during well construction, stimulation, plugging, or abandonment (King and King, 2013). Another important distinction is that the failure of a particular well component (sometimes referred to as "compromised well integrity") does not necessarily indicate that there is a failure of well integrity; wells are designed with multiple barriers to flow, and any remaining barrier that intercepts a potential flow path and prevents formation of a leak path is effective (at the moment it becomes the remaining barrier) in preventing pollution. However, reliance on a single barrier leaves less room for error in maintaining well integrity. Another important distinction in these types of studies is the range of leak paths under consideration. King and King state that "for a well to pollute, a leak path must form and extend from the inner hydrocarbon flow path to the outside environment." (King and King, 2013). This requirement excludes a potential flow path from a non-target gas-bearing formation through the outer annuli and into freshwater aquifers. Such a potential flow path is a primary concern because most occurrences of gas leakage involve gas from relatively shallow, non-target formations that discharge to the annulus of production wells (Dusseault and Jackson, 2014).

In response to numbered comment 17 above regarding the rate of well integrity failure, the reported rates of well-component failures and well-integrity failures vary depending on the types of failures, time periods surveyed, and geographic areas covered. A 2014 study led by Cornell University of over 75,000 Pennsylvania state inspection records for over 41,000 conventional and unconventional oil and gas wells indicated compromised cement and/or casing integrity in 0.7-9percent of the active oil and gas wells drilled since 2000, with a higher frequency for unconventional wells drilled since 2009 than for conventional wells. As noted by the commenter, the study also makes predictions of cumulative (long-term) hazards from compromised integrity exceeding 40 percent (Ingraffea *et al.,* 2014). Compromised well integrity, as explained previously, does not necessarily indicate failure of well integrity. If the failure results in gas leakage through the annulus outside the surface casing, the gas is available to invade shallow formations, including freshwater aquifers.

A 0.5 percent rate of failure of well integrity was estimated by EPA for a representative sample of approximately 28,500 hydraulic fracturing jobs conducted nationally between September 30, 2009, and September 30, 2010 (U.S. EPA, 2016e, p.31). The 95 percent confidence interval for this estimate is 0.1-2 percent. In instances of failure of well integrity, all barriers to fluid leakage were compromised, but no determination was made as to whether fluid migration to water resources occurred. This failure rate applies only to the stimulation part of the gas well life cycle, and it does not include failures occurring during well construction, operation, plugging, or abandonment. As such, DRBC expects that the failure rate inclusive of failures occurring over the entire gas well life cycle is probably higher than 0.5 percent. Other estimated rates of well integrity failure (using different methodologies and over different time periods) for hydraulically fractured wells in Pennsylvania were 0.06 percent, 0.12–1.1 percent, and 0.25 percent (Considine *et al.,* 2012; Brantley *et al.,* 2014; Vidic *et al.,* 2013, respectively). The 0.06 percent figure is from a controversial report whose academician authors had close ties to industry and had not disclosed the conflict of interest in the report. As a direct result of an investigation of the controversy surrounding the report, the substantiation of the report's conclusions, and the undisclosed conflict of interest, the president of the University of Buffalo closed the Shale Resources and Society Institute that had been founded by one of the report authors (Tripathi, 2012). Excluding this value, the range of estimated rates of well integrity failure for hydraulically fractured wells in Pennsylvania is 0.12–1.1 percent.

The Commission recognizes that the environmental risks stemming from HVHF well-integrity issues most frequently involve gas leakage and not liquid leakage, as noted in numbered comment 7 above. When well-integrity failures occur, gas is the most common substance lost (King, 2013). Rapid gas transport in fractures explains how methane can travel vastly different distances and directions laterally away from a leaking well, which leads to variable levels of methane contamination in nearby groundwater wells (Moortgat *et al.,* 2018). Liquid migration within or around the wellbore is improbable during production because the density of the formation liquids is too high for it to be lifted by the natural formation pressure, and because the pressure in the target shale-gas reservoir is depleted with time (Dusseault and Jackson, 2014). Although there have been instances of fluid releases in incidents involving casing rupture (such as blowouts that occurred in Killdeer, North Dakota in 2010 (U.S. EPA, 2015c) and near Powhatan Point, Ohio in 2018 (DiSavino and Palmer, 2018; USEPA, 2018a)), such incidents are uncommon. The detailed documentation of the Killdeer incident and the study of contaminated wells in Bradford County, Pennsylvania (Llewellyn *et al.,* 2015) both demonstrate hydraulic subsurface migration of fracturing fluid and impacts to water resources, controverting the assertion by Halliburton Energy Services, Inc. in numbered comment 9 above that there is "no evidence" of the migration of fracturing fluids into drinking water resources via any subsurface pathway. The Killdeer and Bradford County incidents are described in more detail in this response and in the previous response on migration.

In response to comments on problems associated with deteriorating well-integrity as wells age (numbered comments 10, 14, 15, and 18 above), the Commission recognizes that this is known to be a problem. The long history of conventional gas well production has shown that gas wells can develop gas leaks along the casing years after production has ceased and the well has been plugged and abandoned, as reported by the U.S. Geological Survey (McMahon *et al.,* 2018); and a Canadian study (Dusseault *et al.,* 2000). The deteriorating integrity of the cement sheath providing long-term isolation is a significant, continuing industry problem (Kellingray, 2007). Several studies have documented processes that can result in, and have resulted in, the deterioration of well integrity as wells age. Geochemical reactions between the rock, cement and steel, or the cement, steel, and produced water can corrode the casing as the well matures (Jackson *et al.,* 2014).

The percentage of wells with potential gas migration indicated by sustained casing pressure ("SCP") has been shown to increase as wells age (Watson and Bachu, 2009), indicating that risks of gas migration could increase as wells age. The process of leak development as wells age is initiated primarily by cement shrinkage, which leads to circumferential fractures in the cement that are propagated upward by the slow accumulation of gas under pressure behind the casing. This process is explained in detail by Dusseault, *et al.* (2000). We note that in 2011, Pennsylvania upgraded its well construction regulations (*see* Appendix-4) to require routine monitoring of well integrity by operators and reporting and remediation of problems. However, the research by Ingraffea (2014) described earlier showed that, among unconventional wells of the same age, the risk of impairment for wells drilled between 2009 and 2012 was not significantly different than that of wells drilled between 2000 and 2008.

With regard to numbered comment 13 above that cements used in well construction do not have a documented history of long-term durability, the Commission relies on results of published research and expert commentary on the subject. A study on this issue led by the National Energy Technology Laboratory (NETL) concluded that

> . . . long-term monitoring of zonal isolation performance is a paramount need within the industry to better understand the performance of cement over time; however, current tools and techniques are inadequate either due to cost or lack of appropriate options.

(Kutchko, *et al.,* 2012). Specifically noted was the need for better technology to demonstrate and monitor isolation over the life of the borehole. Although the study was focused on deep offshore wells, onshore wells are subject to the same causes of zonal isolation failure as offshore wells (API, 2016). A 2019 study in British Columbia measured methane flux using flux chambers in the vicinity of 17 gas well pads and detected methane flux at 15 of the pads in discontinuous, unpredictable patterns. The study concluded that fugitive gas may go undetected without appropriate monitoring techniques (Forde *et al.,* 2019a).

With respect to numbered comment 12 above, concerning the variety of causes of well-integrity failure, the Commission agrees and notes that part of the problem is that achieving zonal isolation is complicated. According to Annex D of API Standard 65-Part 2 on Isolating Potential Flow Zones During Well Construction, the design, engineering, and operational framework for successfully isolating a potential flow zone involves multiple steps involving many factors, parameters, and operational considerations (*see* Table 3). These steps include actions such as planning, decisions, assessments, evaluations, calculations, interpretations, modeling, or simulations on all of the following:

Missteps in any of the actions associated with these 65 factors, parameters, and operational considerations could lead to inadequate well integrity, and all of these actions demand sound engineering judgment. In other words, there are many opportunities for component inadequacy or failure to occur. Many types of failures can occur during the step of cement slurry placement alone. George E. King, a distinguished petroleum engineer and author of a textbook on hydraulic fracturing, cites nine references with the following statement on cementing problems:

> Problems in cementing are mostly from poor placement steps, lack of centralization in the casing string and from gas migration through the cement as it sets.

(King, 2012). Some reported examples of cementing problems: If the viscosity and density of the cement and drilling mud are too dissimilar, the cement will not displace the mud properly, but will instead push into the mud in pockets or fingers, trapping fluid and creating channels for flow. Pumping the cement slowly can minimize fingering, but pumping too slowly can result in static settling,

Factors, parameters, and operational considerations involved in the design, engineering, and operational framework for isolating a potential flow zone	Number of factors, parameters, or operational considerations involved
Factors relating to Flow Potential Risk Assessment	3
Critical Drilling Fluid Parameters	3
Critical Well Design Parameters	10
Critical Operational Parameters	11
Critical Drilling fluid Removal Parameters	9
Critical Cement Slurry Parameters	15
Factors relating to Job Execution	8
Special Operational Considerations	6
Total number of factors, parameters, and operational considerations	**65**
	Source: API, 2010, Annex D

Table 3: Flow zone isolation factors

where the cement mixture separates into solid and liquid components. Another reason why the pace of cement pumping must not be too slow is that elevated downhole temperatures can cause the cement to set more quickly than planned, reducing the time available for placing the cement slowly to avoid fingering. Fluid loss from the cement into the formation can result in thickening times that are too short (Soeder, 2017, p.45). Solid/fluid separation in angled or horizontal wells can occur through dynamic settling. Changes in downhole stress can result in instability of the cement, causing fluid to separate. The excess, low density fluid is especially problematic in horizontal wells where it can collect along the upper side of the annulus and form a low-density channel for gas or fluid migration (Greaves and Hibbert, 1990).

As industry techniques and recommended practices have improved, the list noted above has grown, and it presumably will continue to grow as progress continues. In the relatively young industry of hydraulic fracturing of unconventional wells, it is uncertain what new problems and associated impacts will be identified, extending this list and further complicating the process of cementing a well. The stakes are high for completing a cement job correctly. As noted in an article by Gunnar DeBruijn (standards and knowledge development manager for Schlumberger, well integrity) and others in the industry journal "Oilfield Review":

> Engineers and wellsite personnel have only one chance to achieve a successful primary cement job for each casing string. Remedial cementing to solve problems associated with a faulty cement sheath has a less than stellar success rate and may even reduce a well's productivity.

(DeBruijn *et al.,* 2016, p. 19).

The research agrees with numbered comment 10 above that the hydraulic fracturing process can contribute to well-integrity problems. As Daniel Souder, former researcher at the National Energy Technology Laboratory, has explained, after the cementing process is complete, the well may experience cyclic stresses during multiple stages of the HVHF process that can open gaps within the well annulus:

> This [HVHF] process sends pressure pulses down from the surface, and it may stress well casings and cement from the high pressures introduced during the operation. If every annulus between every string of casing is filled with cement, as shown in some well construction diagrams from industry, the high pressures could be transmitted through the steel and cement to the rock surrounding the well. While cement is strong under compression, it is weak under tension, and when the hydraulic fracturing pressure is released, the relaxation and rebound of the steel and cement can create a microannulus at the interface of the cement and rock, or cement and steel. A microannulus can persist for long vertical distances in a well, providing a pathway for gas and other fluids to migrate upward.

(Soeder, 2017, p.72). In addition to being subjected to pressure changes as sequential fracturing stages are started and stopped, the cement sheath is also subjected to variations in pressure within individual fracturing stages. Sixteen or more sub-stages are conducted during each stage to sequentially inject acid, slickwater fluid, slurries with different proppants, and flushing fluid (ALL Consulting, 2012, p. 13; GWPC and ALL Consulting, 2009, p. 59; Mouser, 2019). Surface pressure and bottomhole pressure variations also occur during individual sub-stages (Barth *et al.,* 2012).

The problem of cement-sheath endurance has received international attention, and studies to evaluate failure mechanisms and cement fatigue-endurance limits have been conducted in countries including USA, China, Saudi Arabia, and Norway. While the studies employ different approaches aiming to help improve engineering strategies for improving well integrity, they consistently highlight the depth of the problem. One USA research team observed:

> The cement sheath fails after a certain number of cycles when reaching its fatigue-endurance limit.

(Shadravan *et al.,* 2015). In this laboratory study, cement samples were stressed under temperature and pressure-differential cycles designed to replicate in-situ conditions. The samples failed after as few as 11 cycles. The researchers noted that results do not imply the occurrence of failure scenarios in real wells. A Chinese team conducting similar testing found that, "After 14 cycles, the cement sheath generates radial cracks." (Zhou *et al.,* 2019). A Norwegian team observed that:

> . . . obtaining a good cement job along the planned length of the casing string can be difficult to achieve.
>
> . . . Even if a proper annular cement sheath has proven to be acceptable by means of a pressure test and cement bond logs, the integrity of the bulk cement and bonding to casing and formation may be threatened as a result of

> cement deteriorating and changing downhole conditions over the well life cycle.

(Andrade and Sangesland, 2016). A Saudi Arabia study found that the wellbore permeability of annular cement increases as cement age increases (Ramadan, 2019).

Hydraulic fracturing occurs repeatedly in stages (often 15-20 stages per well, per stimulation event), meaning that the vertical casing strings are subjected to the stimulation pressure stresses described above many times over the lifetime of the well. As demonstrated in a 2014 study by CSI Technologies and Texas A&M University, different cement blends with similar performance properties have different laboratory-determined fatigue-endurance limits, and as a result, some cement blends are more prone to bond failure than others (McDaniel *et al.,* 2014a). The Commission acknowledges that the oil and gas industry is working diligently to improve cementing technology for better performance. Some examples of research topics include: improving the fundamental basis for assessing of cement/matrix strength (Li *et al.,* 2016a); using advanced numerical approaches to simulate cement flow (Grasinger *et al.,* 2015); and using laboratory-scale simulations of cement performance to better replicate wellbore pressure (Li *et al.,* 2018). However, the ultimate benefits of these and other research efforts are yet to be understood. Results of scientific research on long-term well integrity following the application of improved methods that benefit from recent research are not available at present.

Well-integrity may also be compromised by accidents such as explosions, blowouts, and other equipment failures. These events may result in mechanical failure and fluid migration or release. A specific type of accident that can be caused by errors in HVHF well design is interwellbore communication, sometimes referred to as "frac hits." The Energy Resources Conservation Board (now called the Alberta Energy Regulator, or AER) published its Directive 083, which describes interwellbore communication as follows:

> Interwellbore communication occurs when a communication pathway has been established between a subject well and an offset well. A communication pathway may cause a well control event at an offset well, which may result in subsurface impacts or a release of fluids to the surface, placing the public and the environment at risk.

(ERCB, 2013). The offset well may be a well in production, an idle well, or an abandoned well. The total number of existing oil and gas wells in all these categories in Pennsylvania has been estimated to exceed 330,000 (Dilmore *et al.,* 2015). Although there are presently few oil or gas wells in the Delaware River Basin, if HVHF were to be permitted, the number of potential offset wells would be expected to increase, which would in turn increase the risk of interwellbore communication over time as new wells are constructed near older wells. In 2016, the PADEP adopted regulations to address communication with offset wells.

Numbered comment 5 above, asserting that risks due to declining well integrity do not increase over time because pressures decrease over time, conflicts with reliable research contradicting this claim. Although natural gas pressures generally decrease over time to about 20-30 percent of the original pressure (Dusseault and Jackson, 2014), as long as there is enough pressure to reach areas in the well that could be susceptible to integrity issues, there are risks to water resources from the migration of methane and other gases. As noted above, this problem is commonly known in the industry as "Sustained Casing Pressure," or “SCP”. An industry definition of SCP is the following:

> excessive casing pressures in wells that persistently rebuilds after bleed-down. SCP is caused by gas migration from a high-pressured subsurface formation through the leaking cement sheath in one of the well's casing annuli. It may also be caused by defective and leaking tubing connections, downhole accessories or wellhead seals.

(Pegasus Vertex, Inc., 2019). SCP is acknowledged as a common problem in U.S. shale reservoirs (McDaniel *et al.,* 2014b), and faulty well boreholes are a primary pathway of concern for gas migration from gas-bearing formations into shallow freshwater aquifers (Lackey and Rajaram, 2018).

Natural gas production using HVHF together with horizontal drilling to stimulate unconventional wells is a relatively young industry, and as a result, little data exists on aging well-construction materials that have been subjected to hydraulic fracturing and on water resources that may have been or may in the future be impacted. In the Commission’s assessment, the evidence to date suggests that risks stemming from lack of mechanical integrity may be higher for HVHF unconventional wells than for conventional wells. According to a study by the Energy Institute at the University of Texas at Austin, led by Chip Groat, former Director of the U.S. Geological Survey:

> Blowouts due to high gas pressure or mechanical failures happen in both conventional and shale gas development. Shale gas wells have the incremental risk of potential failures caused by the high pressures of fracturing fluid during hydraulic fracturing operations.

(Groat and Grimshaw, 2012). Several important institutional processes contribute to the proper and safe development of a gas well and the success or failure of well integrity and zonal isolation. These processes include: (1) the establishment of industry techniques and standards; (2) government regulation of the industry; (3) systematic independent review and improvement of government regulatory programs; (4) industry adherence to guidance and compliance with regulations; and (5) monitoring of outcomes. Each of these processes plays an important role in ensuring well integrity and zonal isolation. Inadequacies or gaps in any of these processes could result in problems relating to well integrity, migration of gas and/or fluids, and impacted water resources. Uncertainties in each of these processes are cumulative, and the resulting risks posed by failures of HVHF well integrity to shallow aquifers and surface water resources are a major DRBC concern.

Industry Standards and Recommended Practices

With regard to API and other industry comments on industry standards (numbered comments 1-4 above), DRBC recognizes that the oil and gas industry has developed standards, recommended practices, and techniques that have improved over time. API has developed over 600 standards covering all segments of the oil and natural gas industry. API’s published Hydraulic Fracturing Guidelines lists 112 Standards, Specifications, Bulletins, Publications, Technical Reports, and Recommended Practices that support hydraulic fracturing (API, 2019). The robust industry processes for developing and reviewing standards are recognized as demonstrations of industry trade association efforts to recommend practices to develop unconventional gas resources as safely as possible. However, there are important gaps in industry guidance on especially challenging technical procedures, such as cement testing. The issue was evident at least 45 years ago when Continental Oil engineers lamented:

> Despite its potential, the cement bond log is probably one of the most abused, misused, and misunderstood logs used in the oil field today. Miscalibration, inadequate information, and a severe lack of standardization are enough to push petroleum engineers into a morass of bewilderment.

(Fertl *et al.,* 1974). Although there is general API technical information on cement sheath evaluation (API, 2008), the standard for cement testing and evaluation is still missing, according to the following 2015 statement by a Research Consultant source at Chevron Energy Technology with 37 years of experience in the industry:

> The industry has been working to relate cement mechanical properties to success/failure with annular isolation in the actual well for approximately 20 years; however, there are still no American Petroleum Institute standardized cement-testing and evaluation protocols for cement mechanical properties, and there is much room for improvement.

(Carpenter, 2015). Although specific, standardized testing and evaluation protocols have not been established, API in 2008 issued a Technical Report (which conveys technical information but is not a standard) on cement sheath evaluation. The technical report indicates that the industry acknowledges the need to improve the current state of cementing methods and practice. The following excerpt is from page 1 of the API Technical Report on Cement Sheath Evaluation:

> One must understand and never lose sight of the purpose of cement-sheath evaluation. It is ultimately to assess the cement's integrity and ability to achieve its objectives throughout the lifetime of the well. It is not to interpret whether the logs indicate a "good" or "bad" cement bond. Such misguided practice tends to be more prone to error. It can cause financial loss and has, in part, given cement evaluation a bad name. Tools employed in logging operations have various physical limitations that will be described later; for this reason, one must never interpret logs in isolation, without the well and cementing data. Without a clear perspective and strategy for cement-sheath evaluation, one cannot defend against the age-old and often sensible assault.
>
>> *If all we obtain from the logs is comfort when they look good, or discomfort when they look bad, but no confident remedial option, why do we waste time and money running the logs?*
>
> Therefore, performing a cementing job correctly in terms of design and execution is far more important. However, proper evaluation is indispensable,

> and the evaluation process is a powerful tool if used appropriately to improve future jobs."

(API, 2008 (emphasis in original)). The preceding paragraph alludes to an apparent age-old problem of misguided practice in cement sheath evaluation, echoing the lamentations of industry engineers across decades. The intent of the 2008 Technical Report appears to be to educate operators and thereby correct the problem, but the need to include the italicized statement in this guidance document does not inspire confidence in the state of cementing methods and practice. It highlights another reason why so much uncertainty persists about well integrity and zonal isolation: apparently, cement evaluation is difficult and has been considered a waste of time and money. According to a report by Daniel Soeder of the National Energy Technology Laboratory,

> The best way to reduce uncertainty in the interpretation [of cement-testing results] is by running multiple tools that use different methods [using different measurement devices and methods] to measure the cement integrity. Few companies do this, however, because it is a significant added expense.

(Soeder, 2017, p.45). In addition to gaps in sound methods and practice, there is a potentially important element of uncertainty in the applicability of the available guidance. As some industry publications on guidance are careful to point out, some practices may not be applicable in all regions and/or circumstances (ANSI and API, 2015, p. 1), and there always remains a need for applying sound engineering judgment regarding when and where the API guidance is followed (API, 2010, Special Notes, p. iii). The existence of guidance does not mean it is correct nor does it prevent human failings, including failure to follow the guidance. Accidents, mishaps, or mistakes in developing unconventional gas resources can result from poor well construction and operational practices (Considine *et al.,* 2012). They can also result from inexperience, impatience, overconfidence, lack of knowledge, cost-cutting, distractions, or an uncaring attitude (Soeder, 2017, p.67).

An examination of an example of industry guidance brings to light an important limitation of the guidance and some inherent uncertainty that comes with that limitation. Consider the 2015 ANSI/API Recommended Practice 100-2, entitled "Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing" (ANSI and API, 2015). On page 1 of the document is the following statement regarding the conditions of applicability of the recommended practices:

> This document provides technical guidance only, and practices included herein may not be applicable in all regions and/or circumstances.

In other words, there may be regions or circumstances where the recommended practices described in the document may not be appropriate for managing environmental aspects associated with exploration and production operations including hydraulic fracturing. These regions or circumstances are not identified in the guidance, nor is there a specified procedure for determining whether the guidance applies in a given region or circumstance. The applicability of the industry guidance, therefore, is subject to uncertainty. In short, industry guidance on HVHF is substantial, but gaps and confusion persist regarding industry guidance on cement testing and managing environmental aspects.

Regulations

Drinking water resources are protected by a collection of federal, state, tribal, and local laws, regulations, and polices focused on both water quality and water quantity. However, states generally have primary responsibility for protecting drinking water resources from the impacts of hydraulic fracturing activities. In response to numbered comment 11 above to the effect that well casings, cementing, and cement plugs are not regulated to protect aquifers, the Commission disagrees. State oil and gas regulations are in place to help ensure that proper materials are used, proper procedures are followed, sound engineering judgement is employed, and that desired outcomes result. For example, the PADEP's regulations provide that:

> [t]he operator shall case and cement a well to . . . (2) Prevent the migration of gas or other fluids into sources of fresh groundwater. (3) Prevent pollution or diminution of fresh groundwater.

(25 Pa. Code § 78a.81(a)). Despite this and other regulations, impacts to groundwater resources from stray gas have occurred as a result of improper well construction, resulting in the contamination of private wells that render them unusable. An example that is well-documented by Penn State University and the U.S. Geological Survey is the gas well leak that started in 2011 in Lycoming County, PA, contaminated 12 private wells, and caused methane to discharge to nearby streams that have protected water uses of Cold Water Fisheries and Migratory Fishes (Grieve *et al.,* 2018; Woda *et al.,* 2018; Heilweil *et al.,* 2015). In 2015 the PADEP issued an order for the operator to take corrective actions. Corrective actions were taken by the operator, but they were unsuccessful in stopping the gas leak. In 2016 the PADEP requested additional corrective actions, which were attempted but were also unsuccessful. Following two years of inaction by the operator to correct the problem, in January 2020 the PADEP issued another order requiring corrective actions. (PADEP, 2020a) The operator responded to the order by denying responsibility for impacting the water supplies (Legere, 2020). To the Commission's knowledge, the leak continues unabated, contaminating groundwater resources and protected streams.

Some industry standards are incorporated in state regulations, and like industry standards, state regulation of hydraulic fracturing activity is developing and improving with time. For example, in 2011 Pennsylvania's regulations were amended substantially by the addition of enhanced casing and cementing standards for new well construction (Carter *et al.,* 2011). States have considerable latitude in setting regulations, and there is wide variation from state to state in regulations designed to protect water resources (GWPC, 2017, p. 8-21). Pennsylvania's regulations have incorporated some of the latest industry standards, but not all applicable industry standards have been (or realistically can be) incorporated into regulations. Although the Commission has not conducted a thorough, independent review of Pennsylvania's oil and gas regulations to determine what technical improvements could be made, it has studied the largely positive findings of technical reviews of Pennsylvania regulatory programs by other organizations, as described in the following section and in Section 2.1.2, State and Federal Rules, above. Even though Pennsylvania's regulatory program for the most part meets or exceeds the evaluation criteria used by third-party reviewers, adverse impacts from HVHF occur. This supports the Commission's conclusion that the risks to water resources of the Basin from HVHF-related activities cannot be adequately controlled other than by prohibiting HVHF in the Basin.

Compliance

There are different interpretations of the extent of HVHF industry compliance with Pennsylvania regulations and the acceptability of the extent of compliance. Industry claims to take pride in its compliance record and has made broad claims about compliance such as these:

> We comply with regulations, industry standards, and industry best practices and continually update technology that instills confidence in zonal isolation and well integrity for our industry, stakeholders, and society.

(DeBruijn, 2016), and

> . . . a combination of technological advances, existing state and federal regulation, and strict compliance by operators has been sufficient to protect and preserve drinking water resources.

(MSC, 2018, p. 10 (tech.)). However, the record of industry compliance with regulations (as noted by MSC in numbered comment 6 above) requires closer examination. The MSC claims an environmental compliance rate of 97 percent. *See,* MSC, 2018, p. 3 (ltr.)(citing a 2017 MSC evaluation of PADEP inspection, violation and enforcement data). A 3 percent environmental failure rate, if accurate, would present serious risks. The actual failure rate, however, appears to be higher. The percentage of drilled wells in Pennsylvania with polluting events was 52.9 percent in 2008 but improved over the next three years (Considine *et al.,* 2013). Although the rate of compliance with regulations appears to be high on a percentage basis, the consequences of infrequent, yet numerous, instances of non-compliance are a concern. The 2017 PADEP Annual Oil and Gas Report states that unconventional well violations increased from 456 in 2016 to 821 in 2017. The Commission notes that PADEP changed the way it documents ongoing violations (*see* Appendix-4) and that this contributed to the increase. Of the 821 violations in 2017, 67 were administrative-related and 754 were environmental health and safety-related, a number equal to about 5 percent of the 16,296 inspections of unconventional gas wells that year. Of the 754 environmental and safety-related violations, 56 were for "conducting an activity . . . without a permit or contrary to a permit issued by DEP"; 56 were for "failure to prevent gas flow in the well annulus . . ."; 49 were for "failure to plug a well upon abandoning it"; and 42 were for "conducting casing and cementing activities that failed to prevent pollution or diminution of fresh groundwater." (PADEP, 2018b).

Comment 8 above, submitted by API regarding release incidents, appears to underestimate the rate of incidents of unpermitted discharges to waters of the Commonwealth. The comment refers to an analysis by ALL Consulting of Susquehanna County data for 2013-2017 (ALL Consulting, 2018). The ALL analysis of incidents involving the release of materials includes only Clean Streams Law section 401 violations[33] (six violations); it does not appear to include violations of Section 301 of the Clean Streams Law, prohibiting the discharge of *industrial* wastes into waters of the Commonwealth except as authorized by the statute. The characterization of an incident as resulting from a "401" versus a "301" violation in the case of incidents relating to natural gas drilling and production is not clearly

[33] Section 401 of Pennsylvania's Clean Streams Law, 35 P.S. § 691.401, broadly prohibits and declares to be "a nuisance" the discharge to waters of the Commonwealth (including ground waters) of "any substance of any kind or character resulting in pollution as herein defined."

prescribed. Moreover, the ALL analysis does not appear to account for Water Supply Determination Letters (WSDLs) issued by the PADEP, identifying cases where PADEP determined that a private water supply was impacted by oil and gas activities. The PADEP issued 13 WSDLs for wells in Susquehanna County during 2013-17 (PADEP, 2019d). Accordingly, the number of incidents resulting in potential releases to the waters of the Commonwealth would likely be higher than that suggested by the commenter.

Another PADEP report (PADEP, 2018a) provides a summary of the state's Mechanical Integrity Assessment Program, which requires quarterly inspections of well integrity. An analysis of 2014 data showed that less than 1 percent of operator observations indicated the types of integrity problems, such as gas outside surface casing, that could allow gas to move beyond the well footprint. The number of occurrences of gas outside the surface casing was 115 in 23,316 inspection events (0.49 percent). Although this percentage is low, the number of occurrences is substantial. These facts make it abundantly clear that even with a high rate of compliance with updated regulations, many problems, each with potentially severe consequences, can still be expected to result.

Expressed as an aside in their 1990 Society of Petroleum Engineers paper on why wells leak and what should be done about it, Maurice Dusseault of the University of Waterloo and his co-authors weigh in with their own lament:

> we do not believe that the problem can be totally eliminated because of the vagaries of nature and human factors, despite our best efforts.

(Dusseault *et al.,* 2000). A study that examined data on well barrier and integrity failure around the world, with specific analyses of the unconventional Marcellus Shale wells in PA, concluded:

> It is likely that well barrier failure will occur in a small number of wells and this could in some instances lead to some form of environmental contamination.

(Davies *et al.,* 2014).

Well Integrity Outcomes

Pennsylvania oil and gas regulations require weekly inspections of well sites until the well site is stabilized and the earthmoving permit has been terminated, and quarterly inspections are required thereafter; however monitoring of groundwater and surface water conditions is not a requirement, unless in response to a contaminant release incident.[34] Monitoring well integrity outcomes includes performing studies that examine and analyze well-integrity information (described earlier), conducting planned observation of environmental conditions in areas where hydraulic fracturing is taking place (described in Section 2.3.3.3, Groundwater Impacts), and the documentation of incidents in which unintended environmental impacts or potential impacts occur. The Commission agrees with numbered comment 19 above that numerous release incidents have occurred in Pennsylvania and elsewhere as a result of HVHF activity, many of which involved the loss of well integrity. Some

[34] Teleconference with PADEP Office of Oil and Gas Management personnel, March 14, 2019.

examples of unplanned incidents involving well-integrity failure are noted below and in Section 2.3.2.2, Pollution from Spills.

In some instances, mechanical integrity failures during well design or construction or that develop over a well's lifetime have contributed to the movement of gas and/or hydraulic fracturing fluids resulting in impacts to groundwater resources. Over the many decades of oil and gas development in Pennsylvania, failures of well integrity have contributed to hundreds of documented cases of water supply impacts (and in some cases, gas explosions resulting in injuries and fatalities) (PADEP, 2018a). Some cases were severe and resulted in large releases of contaminants or impacts to private and public water supplies. Examples of documented cases of HVHF well-integrity failures occurred in Bainbridge Township, Ohio in 2007 (ODNR, 2008, p. 6; Bair *et al.,* 2010), near Killdeer, North Dakota in 2010 (U.S. EPA, 2015c), in Dimock, PA in 2009 (PADEP, 2009; PADEP, 2010), in Lycoming County, PA (Phillips, 2015; Phillips, 2017), and in the numerous cases of gas migration noted previously. As of September 22, 2020, the PADEP had identified and published 356 cases statewide in which a private water supply was impacted by oil and gas activities. This compilation included impacts by both conventional and unconventional drilling activities and impacts unrelated to well-integrity failure (PADEP, 2019d). Details of these and other cases of impacts to water supplies are presented in Section 2.3.3.1, Drinking Water Resources.

An example of a major interwellbore communication incident (which apparently prompted the Energy Resources Conservation Board of Alberta, Canada to issue its Directive 083, noted above) occurred in Garrington, Alberta on January 13, 2012. A horizontal well was being stimulated and a communication pathway was created between the stimulated horizontal well and a vertical well producing from the same formation 432 feet away, resulting in fluids migrating from the stimulated well to the nearby producing well and the uncontrolled release of hydraulic fracturing fluid and formation fluids to the surface through the vertical well. An estimated 75 cubic meters (about 20,000 gallons) of fluids were released. The cause of the incident was the flawed design of the horizontal well stimulation. According to the ERCB:

> The root cause of this incident was the fact that the planned fracture stimulation size was too large for the separation distance between the two wells.

(ERCB, 2012). A contributing factor in this incident was that the vertical well operator was not notified of the planned stimulation of the neighboring horizontal well and continued producing during the stimulation. Ten days after the incident, the ERCB released a bulletin (and later, Directive 083) requiring operators, among other things, to conduct fracture propagation modelling and to notify offset well owners. As the number of HVHF wells developed in an area increases and distances between well laterals decrease, the risk of interwellbore communication increases. The Commission notes that in 2016 the PADEP adopted regulations to address communication with offset wells.

Accidents on HVHF well pads are an infrequent category of well-integrity failure, but they represent a legitimate risk of substantial environmental impact, and reports on accidents serve as important examples of well integrity outcome. An example is the equipment failure on a Chesapeake Energy well pad in Bradford County, Pennsylvania on April 19, 2011, which reportedly allowed thousands of gallons of HVHF fluid to flow onto the pad, overwhelm containment measures, and discharge into a tributary to the Susquehanna River (Gilliland, 2011). Another example is the reported explosion at an XTO-owned well pad near Powhatan Point, Ohio on February 15, 2018. The explosion damaged the wellhead and caused the loss of control of the well for 19 days. The accident resulted in the uncontrolled release of over 5,000 gallons of HVHF fluid into a tributary of the Ohio River and, by EPA's estimation, the release of 2 billion cubic feet of natural gas to the atmosphere (USEPA, 2018a; DiSavino and Palmer, 2018; Grant, 2018). The cause of the incident was reportedly a pressure buildup that resulted in the failure of a well casing (Grego, 2019). This 2018 incident is particularly troubling, as it occurred after several years of industry progress in the development of standards and best practices, which API described (one month after the XTO incident) as resulting in "significant improvements to system integrity, reliability, and integrated safety." (API, 2018, pp. 1-2).

The experiences in Pennsylvania and elsewhere, as documented in studies furnished in comments submitted to the DRBC and in additional studies referenced in this response, demonstrate that the migration of gas and other fluids as a result of compromised or degraded well integrity can contaminate water resources and drinking water supplies. The many documented incidents of well integrity problems and impacts demonstrate that even with improved regulations and industry best practices, it is likely that the migration of gases and HVHF fluids will result in contamination of water resources in the Delaware River Basin if this activity is permitted. An accurate prediction of the frequency and severity of long-term impacts to water resources as a result of faulty well construction will not be possible until conclusive results are obtained from long-term monitoring of well-construction materials and impacted water resources, and until results of migration pathway studies of incidents and long-term groundwater flow conditions become available.

In conclusion, the Commission appreciates the complexities involved in high volume hydraulic fracturing and developing unconventional gas wells, and the industry's efforts to develop and promote effective standards and recommended practices for the protection of water resources. The Commission recognizes the many factors and challenges that come into play in achieving the goals of well integrity and zonal isolation over the life cycle of an unconventional gas well. It also recognizes that the technology of hydraulic fracturing is relatively young and continues to evolve. But the Commission is equally cognizant of the many factors and challenges that come into play in *knowing* whether well integrity and zonal isolation have been achieved and whether impacts to water resources have occurred. The science behind our understanding of HVHF impacts to water resources is relatively young and continuing to evolve. A consequence of the continuing evolution of the technology and the science is a high level of uncertainty regarding impacts, including long-term impacts stemming from the aging of materials. Daniel Soeder, a former researcher at the DOE National Energy Technology Laboratory and former STRONGER review team member, describes the importance of the uncertainty issue this way:

> Questions certainly can be raised about the long-term performance of shale gas wells, including issues related to possible deterioration of cement or steel well casing. . . . Gaining a better understanding of the factors that affect the integrity of gas wells over long time periods is a critical uncertainty that must be addressed for the future development of gas resources.

(Soeder, 2017, p.120). Industry's efforts to establish and implement standards, and the efforts of state and federal regulators to craft rules and ensure compliance are not always successful, and while the probability of failure is low, the consequences of failure and the impacts to water resources, as the short history of HVHF has shown, can be severe.

RISKS TO WATER RESOURCES FROM FLUID MIGRATION - SUMMARY

After carefully considering the numerous comments the Commission received on potential risks to water resources of the Basin from pollution caused by gas and other fluid migration associated with high volume hydraulic fracturing, and after evaluating a decade of scientific and technical data and literature on this topic, the Commission has found:

- Risks to water resources from high volume hydraulic fracturing and related activities include releases of methane, chemicals, and highly contaminated fluids, and the migration of these substances to groundwater and surface waters.

- Numerous scientific papers and reports document occurrences and evidence of the presence of gas and/or suspected hydraulic fracturing fluids or produced water in groundwater in different settings and circumstances. Although several other studies report little or no evidence of migration of gas or fluids, the weight of the evidence indicates that high volume hydraulic fracturing and related activities can and have resulted in the migration of these substances through artificial and/or natural pathways, resulting in adverse impacts to water resources.

- On the basis of the peer-reviewed literature to date, DRBC finds that the probability of fluid migration is low in "typical" unglaciated, tectonically tranquil shale-gas settings where the target formation is deep, flat-lying, and characterized by low permeability, and in which gas wells are constructed and maintained properly. In other circumstances, the probability of migration may be substantially higher.

- The probability of fluid migration as a result of HVHF may be substantially higher in settings other than those described in the first sentence of the preceding paragraph as "typical." The northeastern Pennsylvania setting, which includes portions of the Basin, is *a*-typical, in the sense described above. Numerous documented incidents of impacts to water resources have occurred in connection with natural gas extraction in northeastern Pennsylvania. The causes have included, among others, improper well construction and/or maintenance, and/or the natural geologic characteristics of this region.

- Research has demonstrated that local geology can help explain why fluid migration to aquifers sometimes occurs in areas of HVHF activity. The geologic setting in northeastern Pennsylvania and southern New York may be more prone to potential migration and impacts to water supplies than are more "typical" shale-gas settings such as those of the Marcellus Shale in central and western Pennsylvania, and those of other shale-gas areas in Texas, Colorado, Wyoming, North Dakota, and Montana.

- The likelihood of induced seismicity in the DRB as a result of development of Marcellus Shale gas, and the subsequent migration of gas or fluids through pathways generated by HV-induced seismicity appears to be low. The likelihood of induced seismicity in the DRB as a result of development of Utica-Point Pleasant shale gas may be less certain.

- The literature makes evident that technical problems during the complex process of cementing gas wells have plagued the industry for decades. The process requires sound engineering judgment in conducting actions on 65 critical parameters, factors, and operational considerations. After the cementing process is complete, the well may experience cyclic stresses during the HVHF process that can open gaps within the well annulus, resulting in leaks. No American Petroleum Institute standardized protocols exist for cement-testing and evaluation of cement mechanical properties.

- Reliable studies of the frequency of well integrity failure during well stimulation (a single phase of a well's life cycle) in Pennsylvania indicate a range of results from 0.12-1.1 percent.

- As a result of metal corrosion and/or cement shrinkage, gas wells can develop gas leaks along the casing years after production has ceased and the well has been plugged and abandoned.

- Failures of well integrity associated with HVHF would in the Delaware Basin allow the migration of fluids into groundwater and surface waters the quality of which is to be "preserve[d] and protect[ed] in a safe and adequate condition for the uses specified in the Comprehensive Plan." (WQR § 4.10). For ground water, these uses include "domestic … and public water supplies;" and "a source of surface water suitable for recreation, wildlife, fish and other aquatic life." (WC § 3.40.3).

- Even with a regulatory program highly rated by STRONGER and a high rate of industry compliance with regulations, many pollution events with severe consequences have occurred in regions outside the Delaware River Basin. If high volume hydraulic fracturing were to proceed within the Basin, such events would occur in the Basin as well, and by impairing or foreclosing protected water uses, would substantially impair or conflict with the Commission's Comprehensive Plan.

- The Commission agrees with and relies on EPA's understanding and interpretation of the peer-reviewed scientific research published through 2016, including the EPA's conclusions that hydraulic fracturing activities can impact water resources under some circumstances; and that such impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors.

- After EPA issued its final report on Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States in 2016, additional research was published reinforcing EPA's conclusions and providing additional evidence that in the regions in which it is permitted, HVHF is accompanied by adverse impacts to water resources. The observed effects on water resources described in the literature to date are effects that within the Delaware River Basin would constitute substantial impairment and conflict with the Commission's Comprehensive Plan.

In view of the above, the Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, primarily: in rural areas dependent upon groundwater resources, in sensitive headwater areas considered to have high water resource values, and in areas draining to DRBC Special Protection Waters. As has been demonstrated in regions outside the Basin, losses of well integrity would occur, resulting in subsurface migration of harmful pollutants into groundwaters the Commission has designated as sources of drinking water. The pollutants would include gas, salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined, impairing such designated use. These events would be dispersed over thousands of acres of sensitive water resource features, in a region characterized by extensive geologic faults and fractures.

A decade of experience in other regions has shown that regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills, gas and other fluid migration, and releases of chemicals and hydraulic fracturing wastewater. Accordingly, the Commission has determined that controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.2.4 Pollution from Wastewater Treatment and Disposal

This subsection addresses comments concerning wastewater handling and disposal from HVHF activities. If HVHF activities were to be permitted in the Delaware River Basin, wastewater from the process would need to be stored, handled and transported within the Basin and potentially treated and disposed of within the Basin, within or outside the state of origin.

Comments that are related solely to the importation of wastewater or to the treatment and discharge provisions set forth in proposed rule Section 440.5 are not addressed in this document because proposed Section 440.5 has been withdrawn from the Commission's consideration. In this document, the terms "produced water", "flowback water", and "fracturing fluids" and other terms used to describe HVHF wastewater are aligned with definitions used by the EPA. *See,* U.S. EPA, 2016b, pp. xiii-xv. *Also see,* Appendix 2 – Glossary of Wastewater Terms in this Comment and Response Document.

STATEMENT OF CONCERN (SC-36)

Many commenters provided data, information and opinion about the handling, treatment and disposal of wastes generated by high volume hydraulic fracturing activities. These wastes primarily include flowback water and produced water (i.e. fluids used in the hydraulic fracturing process as well as formation fluids and transformation products that return to the surface following completion of a well and during and after production) and will be the focus of this specific response. Certain concerns addressed impacts to water resources from hydraulic fracturing chemicals and additives used in the well drilling and production phases as well as dissolved material such as salts/brines and radioactive substances returning to the surface. Some commenters expressed concern about HVHF wastewater in general and its impact upon the water resources of the Basin. Others argued that hydraulic fracturing is safe and/or that DRBC's proposed regulations were unnecessary or unjustified.

PARAPHRASED COMMENTS FROM THOSE WHO GENERALLY SUPPORT SECTION 440.3 OF THE DRAFT RULE (AND GENERALLY OPPOSE HYDRAULIC FRACTURING) IN THE DELAWARE RIVER BASIN INCLUDE:

- Hydraulic fracturing wastewaters are complex and variable, fraught with uncertainties about identity and composition, and inherently distinct from other types of wastewater for which DRBC now issues dockets. The only meaningful option for controlling such wastes is to prohibit them altogether.

- The HVHF process yields wastewater containing over 1,000 contaminants that can cause significant harm to human health, wildlife and the environment, and there is no safe way to handle, treat, and dispose of all this hydraulic fracturing wastewater. The only way to eliminate the outsized risk of exposing people, wildlife, and the environment to this contamination is to prohibit its storage, treatment, processing, disposal, and discharge in the Basin.

- There are no treatment options that can remove the contaminants in a cost-effective manner; until such a process is developed, discharge of HVHF water should simply be banned within the Basin to avoid the unreasonable risk of contamination to drinking water resources as well as ecological harm to waters in the lower portion of the Basin.

- Improper disposal of produced wastewater poses a significant risk to the water resources of the Basin. This waste stream is unlike other industrial and domestic waste streams. It poses significant risks to human health and the environment if improperly handled.

- If treatment of hydraulic fracturing wastewater is permitted in this region, the DRBC should establish adequate water quality standards for all chemicals that could be present to ensure wastewater has been properly treated and harmful chemicals have been neutralized.

- The oil and gas industry waste fluids classified as "brines" contain large concentrations of toxic substances including heavy metals (barium, chromium, cadmium, and lead), volatile toxic chemicals (including benzene, ethylbenzene, toluene and xylene - often referred to as BTEX), surfactants (such as 2-butoxyethanol), pesticides, corrosive materials (chlorides, bromides, and ammonium), carcinogenic and radioactive substances including uranium, radium, radon, and the radioactive decay artifacts of these elements.

- The handling of residual contaminants removed by evaporative or membrane processes, and thus concentrated to form even more contaminated wastes, was not discussed in the draft regulations, other than to indicate that residual salts or concentrated brine will require "further treatment or disposal". Some of the fracking produced water has been recycled several times making it a highly potent toxic solution.

- Pollutants can spread downstream to negatively impact all the watershed states, the habitats, fish, wildlife, and recreational values of the river and our vulnerable drinking water supplies.

- There is no step-by-step accounting of hydraulic fracturing water flowback.

Paraphrased comments from those who generally oppose Section 440.3 of the draft rule (and generally support hydraulic fracturing)

- Government data and scientific research show that hydraulic fracturing is safe and does not contaminate drinking water. Given this evidence, DRBC's proposed rule goes too far. DRBC's proposed rules to ban hydraulic fracturing are neither scientifically based nor realistic.

- The federal government creates framework environmental laws that often prescribe regulatory minimum thresholds for states to follow. For example, the Clean Water Act ("CWA") applies to oil and natural gas operations. The CWA allows for the establishment of the National

Pollutant Discharge Elimination System ("NPDES"), which, in most states, regulates how oil and natural gas operators manage wastewater discharges from their sites.

- Specific to Pennsylvania, in 2010 DEP established new regulations affecting the discharge of produced water with elevated total dissolved solids ("TDS"). The regulations established four revised effluent standards for TDS, chlorides, barium, and strontium – which publicly-owned treatment works ("POTWs") and centralized waste treatment ("CWT") facilities were required to meet. In May of 2011, DEP asked operators to stop discharging shale produced water to POTWs and CWTs because of water quality concerns downstream of municipal discharge points. PADEP wastewater management plans require that wastewater (fluids) must be recycled, treated at an authorized wastewater treatment facility, or disposed at an authorized waste disposal facility. DEP approval is required before the receiving treatment or disposal facility can accept the wastewater for processing and/or disposal.

- Some of the water and wastes resulting from exploration and production of oil and natural gas may contain low levels of radioactivity through contact with underground formations. The industry operates under federal, state, and local regulations to manage, store and dispose of these materials in a safe manner, which protects both workers and the community. Low levels of naturally occurring radioactive material (NORM) are all around us. They are in the foods we eat and the houses we live in, and in the air, rocks, and soil in the environment.

- In 2016 the US EPA Technical Development Document attempted, but failed, to characterize the pollutants in unconventional oil and gas waters. Therefore, DRBC should not consider there to be any pollutants of concern in oil and gas wastewater.

- DRBC's proposal to prohibit HVHF operations in the Delaware River Basin is an extreme overreaction based upon either a misunderstanding or a misinterpretation of the most current and accurate information about the level of risk to surface water and groundwater sources from HVHF operations.

- Significant advancements in the technical and energy efficiency of desalination technologies allow for the effective removal of Total Dissolved Solids (TDS), which will allow for the successful treatment of produced water and not pose a harm to public health or safety.

- Given the rapid changes and innovations in the oil and natural gas industry and the importance of maintaining non-consumptive water options, DRBC should preserve companies' flexibility to manage produced water. Prohibiting present and future wastewater management options will not advance environmental protection or improve water quality.

- Where hydraulic fracturing may cause adverse impacts under certain conditions, the natural gas industry has addressed those potential impacts for years using a three-prong approach:

    - Ever-improving industry practices (backed by industry-recognized standards),

    - Robust state regulatory programs, and

    - Federal regulations.

Response (R-36)

Introduction

The DRBC acknowledges the comments highlighting the unique and complex nature of the wastes generated during hydraulic fracturing operations. For the reasons outlined below, we disagree with commenters who suggest that the proposed regulations are not scientifically based. The Commission has carefully considered currently available scientific and technical information about the level of risk to surface water and groundwater and agrees with the conclusions of comprehensive reports on the subject by EPA and the State of New York as described below.

The Commission recognizes efforts by the oil and gas industry to develop unconventional gas resources as safely as possible. In addition, the research has indicated and the Commission also recognizes that some of the historical impacts from wastewater handling are due to practices for the disposal of conventional wastewater; however, the Commission has concluded that the collection, storage, handling, transport, treatment, discharge, and disposal of wastewater from high volume hydraulic fracturing activities presents significant risks, vulnerabilities and impacts to the water resources of the Delaware River Basin.

Shale gas development through unconventional drilling (i.e. hydraulic fracturing) is an industrial activity that entails some categories of risk generally shared by other industrial, commercial, and agricultural development activities and others that are specific to this activity. As explained in greater detail below and in other sections of this document, the activities and materials associated with unconventional gas development pose particularly severe risks which can result in, and have resulted in, significant impacts to surface and ground waters and to protected uses that include drinking water and aquatic life. Furthermore, the long-term impacts of this relatively young phase of the industry on surface water, groundwater and aquatic life are not fully understood.

Background

The process of HVHF results in significant volumes of a unique class of wastewater known as "flowback", "produced water" or "oil and gas wastewater" that must be contained, stored, and reused, treated, discharged and/or disposed. (HVHF can produce other wastes such as drilling mud or drill cuttings; however, these classes of wastes are not addressed in this response.)

The U.S. EPA has provided a full characterization of produced water and a comprehensive discussion of wastewater disposal and reuse (*see* U.S. EPA, 2016a, Chapters 7 and 8, respectively). For the purposes of this comment response, consistent with U.S. EPA (2016a), the term "produced water" will be used to refer to fluid flowing from the gas well.

The Commission also agrees with the conclusion of the New York State Department of Environmental Conservation that:

> Proper treatment, management and disposal of wastewater from HVHF present a number of potential significant adverse environmental and health impacts for which adequate mitigation has not yet been determined.

(NYSDEC, 2015a, p. RTC-152)

In responding to comments concerning HVHF wastewater, the Commission staff relied on four additional studies developed by or at the direction of technical agencies of its signatory parties, including:

1. EPA's June 2016 report entitled: *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category* (U.S. EPA, 2016b). Wastewater specific to shale development in the Marcellus Shale formation is characterized in this EPA report. EPA's primary purpose for the report was to enable the agency to develop a final Clean Water Act regulation that would better protect human health and the environment by maintaining the operational integrity of publicly owned treatment works ("POTWs"). The purpose of the EPA regulation was to establish pretreatment standards to prevent the discharge to POTWs of pollutants in harmful concentrations in wastewater from onshore unconventional oil and gas ("UOG") extraction facilities. The EPA report recognizes that UOG extraction wastewater can be generated in large quantities and has constituents that are potentially harmful to human health and the environment. Because these constituents are not typical of POTW influent wastewater, and typical POTW processes are not designed to treat them, some UOG extraction wastewater constituents can be inadequately treated and discharged from the POTW to the receiving stream; can disrupt the operation of the POTW (e.g., by inhibiting biological treatment); can accumulate in biosolids (i.e., sewage sludge), limiting its use; and can facilitate the formation of harmful disinfection byproducts ("DBPs") downstream and in public water supply systems that rely on the receiving stream as source water (*see,* U.S. EPA, 2016b, p. 1).

2. PADEP's 2015 TENORM Study (updated May 2016) (prepared by Perma-Fix Environmental Services), which analyzed the naturally occurring levels of radioactivity associated with both conventional and unconventional oil and natural gas development in Pennsylvania. While the report outlines recommendations for further study, it concludes there is little or limited potential for harm to workers or the public from radiation exposure due to the development, completion, production, transmission, processing, storage, and end use of natural gas (Perma-Fix, 2016). However, the report does identify potential radiological environmental impacts from oil and gas fluids if spilled, and a potential long-term issue associated with filter cake disposal.

3. EPA's 2018 study entitled: *Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes.* EPA's primary goal in this study was to determine whether its existing CWT regulations should be updated in response to changes in the industry that could affect facilities accepting oil and gas extraction wastes. The report provides details on direct and measurable impacts on surface water quality and sediment from discharges by existing CWT facilities that treat oil and gas wastewater, and the potential impacts from these discharges to human health and aquatic life. The results and conclusions of this study informed DRBC's understanding of the characteristics of HVHF wastewaters, as well as the risks and impacts to water resources from discharges of treated oil and gas wastewater by CWTs and as the result of inadvertent releases (i.e. without treatment of any kind) (U.S. EPA, 2018b).

4. EPA's 2020 study evaluating management of produced waters from onshore oil and gas extraction activities. EPA issued results of the study in a draft report (U.S. EPA, 2019) and in a final report (U.S. EPA, 2020a). The stated goals of this study were to: (1) evaluate approaches

to manage onshore oil and gas extraction wastewaters; and (2) understand any potential need for additional discharge options and concerns associated with identified options. That is, EPA wished to determine whether any actions are appropriate to further address oil and gas extraction wastewater (U.S. EPA, 2020a). EPA conducted outreach to a variety of stakeholders nationwide, including state agencies, oil and gas industry members, tribes, NGOs, members of academia, and other entities. Of concern to the Commission is that this report appears to emphasize the exploration of additional discharge options, including revising effluent limitations guidelines and standards ("ELGs") to allow for "broader discharge" of produced water, rather than to address the documented impacts to surface water quality from discharges by existing CWTs (as set forth in detail in U.S. EPA, 2018b). Among the themes communicated to EPA from oil and gas industry members was "concern over the ability to meet water quality standards in certain areas where surface waters are of high quality." The Special Protection Waters of the Delaware River Basin are surface waters of high quality. Oil and gas industry members further communicated that, "If the costs and regulatory burden for managing produced water are too high, certain areas may not be developed. In addition, areas that are currently producing resources may need to be prematurely shut-in if produced water management costs significantly increase." (U.S. EPA, 2020a, p. 27).

As noted in Section 2.3.2.1, Water Use, of this Comment and Response Document, the average volume of fluid used per hydraulic fracturing event has increased significantly to accommodate the expanding depth and length of directional drilling. Over time, industry has extended the horizontal lateral portion of unconventional natural gas wells further through the targeted shale formation and has deepened wells to reach the Utica Shale formation (Konrath *et al.,* 2018). As a result, the quantity of flowback and produced water returned to the surface overall (not simply per well) is expected to increase in Pennsylvania. Rahm *et al*. (2013) reported that 6 million meters^3 (or nearly 1.6 billion gallons) of wastewater had been generated in the process of extracting natural gas from shale in Pennsylvania alone between 2008 and 2011. Kondash *et al*. (2017) found that, on average, unconventional oil and gas wells yield a range of between 0.5 and 3.78 million gallons of produced water during the first ten years of production. EPA found that a range of 420,000 to 1.3 million gallons of produced water was recovered from each Marcellus shale well in the Susquehanna River Basin between 2008 and 2013 (U.S. EPA, 2016a, p. ES-14 (Figure ES-4a)).

The EPA estimated that 90 percent of produced water from the Marcellus Shale in the Susquehanna River Basin in Pennsylvania was recycled and reused in the hydraulic fracturing process (U.S. EPA, 2016a, p. ES-14 (Figure ES-4a)). A similar estimate was provided by David Yoxtheimer of the Penn State Marcellus Center for Outreach and Research. Yoxtheimer (2014) reported an 87 percent recycle rate and a 10 percent disposal rate at regulated underground injection wells. In the same presentation, Yoxtheimer stated that of the recycled water, 22 percent was disposed of via centralized treatment and surface water discharge. However, the produced water that is recycled is normally highly diluted with additional fresh water to make up the necessary volumes. According to the American Geosciences Institute, "[T]he Marcellus Shale in the northern Appalachians produces very little water compared to other major oil- and gas-producing regions [(citing Kondash *et al.*, 2017)]. Almost all of the produced water is reused in hydraulic fracturing operations, but the small amount of water produced compared to the amount used means that produced water can provide only a small fraction of the water needed for hydraulic fracturing in this area [(citing Vidic and Yoxtheimer, 2017)]." (Allison and Mandler, 2018).

According to EPA, Pennsylvania has 57 CWTs accepting oil and gas wastewater (the report does not specify whether the waste is from conventional or from unconventional well sources), the highest number of any state in the United States (U.S. EPA, 2018b, p. 8-4). Although a significant volume of wastewater may be recycled, the pollutants in unrecycled wastewater and their loads require treatment and disposal. In 2012, 2.3 percent of produced water in Pennsylvania was discharged to surface waters (Veil, 2015, p. 94 (Table 5-52)).

Characterization of Hydraulic Fracturing Wastewater

Because wastewater from HVHF poses risks to water resources through spills and other inadvertent releases, faulty casings and cementing, subsurface migration, partially treated discharges and other means, knowing its composition is important to evaluating risks and impacts. Following stimulation of an unconventional gas well (i.e. injection of fracturing fluids under high pressure into the target formation), residual fluids gradually return to the surface, first as flowback and, subsequently, as produced water. Produced water contains: base fluids (most often water), proppants (most often sand) and additives used in hydraulic fracturing fluids; saltwater naturally found in the pore spaces of the targeted rock formation, which can contain varying amounts and types of metals, radioactive materials, hydrocarbons (e.g., oil and gas), and other chemicals; and chemical products that are formed when chemicals in hydraulic fracturing fluids undergo chemical reactions, degrade, or transform (U.S. EPA, 2016a, p. ES-33-35). Most of the injected fluid remains underground, while roughly 10-30 percent returns to the surface (U.S. EPA, 2016a, p. ES-34). Produced water that returns to the surface flows from the wellhead to on-site storage facilities before being transported offsite via truck, rail or pipeline for treatment, disposal and/or reuse.

According to U.S. EPA (2018b, p. 1-2), "oil and gas extraction wastes can contain a variety of constituents, including biochemical oxygen demand ("BOD"), bromide, chloride, chemical oxygen demand ("COD"), specific conductivity, sulfate, total dissolved solids ("TDS"), total suspended solids ("TSS"), barium, potassium, sodium, strontium, benzene, ethylbenzene, toluene, xylenes, sulfide, gross alpha, gross beta, radium 226, and radium 228," as well as chemicals contained in injection fluids. The chemistry of produced water changes over time, especially during the first days or weeks following hydraulic fracturing. Generally, concentrations of cations, anions, metals, naturally occurring radioactive material ("NORM"), and organics in produced water increase over time (U.S. EPA, 2016a, p. 7-12).

EPA has reported the following characteristics of HVHF wastewater:

> Total Dissolved Solids (TDS): Produced water commonly has high concentrations of TDS. The concentration of TDS in produced water from the Marcellus Shale formation has been reported to have a range of 10,000 - 300,000 mg/L. The TDS concentration of seawater is about 35,000 mg/L. High concentrations of TDS degrade the potability of drinking water, generally on the basis of taste, and can corrode water conveyance pipes. High levels of TDS also negatively affect aquatic biota through increases in salinity, loss of osmotic balance in tissues, and toxicity of individual ions. Increases in salinity cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species and cause acute or chronic effects at specific life stage. High TDS levels can also adversely affect agriculture irrigation and livestock watering.

HALIDES: High concentrations of halides (e.g., bromide, chloride, iodide) are often present in produced water and in the discharged effluents from CWT facilities treating O&G wastewater that lack specific technologies for their removal. Halides in TDS originate from the rock and brine formations. At high concentrations, halides such as chloride can be directly toxic to aquatic organisms. Halides also pose potential drinking water concerns due to their reactivity and potential to form disinfection byproducts (DBPs) that can adversely affect human health.

METALS: Wastewaters from HVHF commonly have high concentrations of metals, including barium, calcium, iron, magnesium, manganese, and strontium. These metals occur naturally in the brines located within shale formations. EPA has established chemical-specific national recommended water quality criteria for some of these metals (e.g., Ba, Mn, Fe) based on a variety of human health or ecological benchmarks. Produced waters and CWT facility effluent have been reported to routinely exceed many of these criteria.

RADIOACTIVE SUBSTANCES: Naturally occurring radioactive materials (NORM) primarily come from uranium-thorium decay sequences (e.g., Ra226, Ra228) and are present in virtually all environmental media, including rocks and soils. These radionuclides can become mobilized through HVHF, and as such, are technologically enhanced or TENORM. Soluble radionuclides are commonly present in produced water, with the specific makeup of nuclides and isotopic composition dependent on the geological formation. HVHF and shale gas drilling operations bring TENORM to the surface during production operations because subsurface geologic formations commonly contain higher amounts of radioactive isotopes than surface rock or soil, and radioactive isotopes desorb into solution at high salinity. TENORM can be present in CWT effluent and can, under certain environmental conditions, precipitate out in receiving waters or be incorporated into downstream sediment. TENORM can also concentrate in waste sludge generated by CWT processes, resulting in materials that have radioactivity levels exceeding the ambient levels in the geologic formations. For more discussion about radioactivity in produced water and potential risks see Section 2.3.2.2, Pollution from Spills.

OTHER CONSTITUENTS: Other potential pollutants in wastewater from HVHF activities include chemicals contained in injection fluids, such as surfactants, biocides, wetting agents, scale inhibitors, and organic compounds. The composition of some hydraulic fracturing chemicals is disclosed to the public, while the composition of others is considered confidential business information (CBI). For more information about CBI chemicals, refer to Section 2.6.2 in this document. In a study of hydraulic-fracturing fluids and wastewater from unconventional oil and natural gas development, Elliott *et al*. (2017) systematically evaluated 1021 chemicals identified in hydraulic-fracturing fluids (n=925), wastewater (n=132), or both (n=36) for potential reproductive and developmental toxicity to identify those with potential for human health impact. The researchers found that toxicity information was lacking for 781 (76%) chemicals. Of the remaining 240 substances, evidence suggested reproductive toxicity for 103 (43%), developmental toxicity for 95 (40%), and both for 41 (17%).

See, U.S. EPA, 2018b, pp. 9-1 – 9-4. Additional information about additives and chemicals used during the drilling process and the toxicity of those chemicals is discussed in Section 2.3.2.2, Pollution from Spills.

Many chemicals used in HVHF are known to be hazardous. That is, they are carcinogenic, neurotoxic or endocrine disrupting, or have immune system effects or reproductive and developmental toxicity. Although a lack of information regarding the toxicity of specific chemicals is not unique to HVHF, the majority of chemicals associated with hydraulic fracturing have not undergone significant toxicological assessment (U.S. EPA, 2016a, p. ES-42-45, 9-1).

Wastewater Regulations

In U.S. EPA (2019), the EPA's study goal was to evaluate approaches to manage oil and gas extraction wastewaters generated at onshore facilities, including but not limited to an assessment of technologies for facilities that treat and discharge oil and gas extraction wastewaters to surface waters. The EPA obtained input from a variety of states, tribes and stakeholders concerning produced water management under the Clean Water Act ("CWA"). While some entities were supportive of expanding discharge opportunities that would increase flexibility, reduce costs, and increase available water supplies, others opposed such expansion due to concerns about environmental or human health implications. The EPA indicated that it intends to consider the information obtained during the outreach activities before determining next steps for produced water management under the CWA.

The background for the EPA study indicates that large volumes of wastewater are generated in the oil and gas industry, and these volumes are expected to increase. At present, the majority of this wastewater (consisting mostly of produced water) is disposed of by means of underground injection, through which the wastewater is injected into deep wells and can no longer be accessed or used. As the limits of injection capacity are evident in some areas, new approaches are becoming necessary. Some states and stakeholders, particularly in water scarce areas of the country, are evaluating steps to treat and reuse the wastewater for other purposes. As noted earlier, the natural gas industry in Pennsylvania disposes of only about 10 percent of its wastewater by underground injection. However, EPA's 2020 report could have national implications as the EPA looks for opportunities to extend the treatment and discharge of HVHF wastewater. Currently, direct discharges of pollutants from produced water to surface waters are prohibited. Discharges of oil and gas wastewater are subject to EPA's oil and gas extraction effluent limitations guidelines and pretreatment standards ("ELGs") set forth at 40 C.F.R. Part 435. As revised in 2016 this set of regulations prohibits the discharge of pollutants from unconventional oil and gas extraction activities directly to POTWs. *See,* 81 Fed. Reg. 41845 (June 28, 2016). Discharges to surface waters from CWT facilities that accept produced water are subject to ELGs found at 40 C.F.R. Part 437.

The PADEP in 2010 amended its wastewater treatment requirements under the Clean Streams Law for new and expanding discharges of TDS (*see* 25 Pa. Code § 95.10). Discharges that commenced before August 2010 were generally exempt from the new requirements, although any modification of such a discharge would require approval. Because of concerns about water quality downstream of municipal wastewater treatment plants exempt from the new requirements, the PADEP in May of 2011 asked operators to stop sending produced water from shale gas extraction to such facilities (PADEP, 2011). While the best information available to DRBC indicates that operators are complying with the PADEP request, no law or regulation fully prohibits the treatment and discharge of oil and gas wastewater by municipal wastewater treatment plants not designed to manage these wastes.

Under 25 Pa. Code § 95.10, new and expanding discharges of treated wastewater resulting from hydraulic fracturing may be authorized by the PADEP provided that the following requirements are met:

- Discharges are from facilities classified as CWTs
- The discharge contains no more than 500 mg/L of TDS as a monthly average
- The discharge contains no more than 250 mg/L of total chlorides as a monthly
- The discharge contains no more than 10 mg/L of total barium as a monthly average
- The discharge contains more than 10 mg/L of total strontium as a monthly average

Wastewater Treatment Effectiveness

Studies of wastewater treatment effectiveness reveal that produced water from high volume hydraulic fracturing contains constituents that can cause adverse impacts to water resources even after treatment. While certain commenters suggested that the current EPA and state rules are effective in managing treatment, discharge and/or disposal of wastes, several studies have highlighted potentially significant risks and impacts to water resources under recent or current practices. The effectiveness of centralized wastewater treatment was examined by EPA in 2018 (U.S. EPA, 2018b). EPA outlined numerous risks and adverse impacts to water resources from CWT effluent and also found that analytical methods of detection and effluent guidelines are not available for the full range of constituents in wastewater from HVHF activities (U.S. EPA, 2018b, p. 1-3). Other examples of impacts to surface waters from HVHF wastewater handling are described in Section 2.3.3.2, Surface Waters and Aquatic Life of this Comment and Response Document. These include the following, among others:

- U.S. EPA (2018b, pp. 9-9 – 9-10) showed that TDS concentrations in waters from a CWT discharge were usually above the secondary drinking water maximum contaminant level ("SMCL") of 500 mg/l, which can be harmful to freshwater aquatic life. The toxicity of TDS to aquatic organisms can vary widely depending on its ionic composition (Mount et al., 1997).

- A focused study that established background water quality in western Pennsylvania streams and showed that the impacts on one such stream of effluent from a facility that exclusively treated oil and gas wastewaters showed that the effluent increased downstream concentrations of chloride and bromide to above background levels (Warner *et al.*, 2013a). The study provides a historical record of surface water impact from the facility and demonstrates that effluent from CWT facilities treating HVHF wastewater can lead to persistent sediment contamination many miles downstream.

- Geeza *et al.* (2018) evaluated the accumulation of metals in the shell material of bivalves as a marker to trace historical upstream wastewater discharges. The findings suggest not only that freshwater mussels can be used as chemical recorders of HVHF wastewater contaminants in waterways, but that wastewater contaminants likely bioaccumulated in areas of surface discharge. Observed changes in the ratios of strontium/calcium and in strontium isotope ratios in shells collected downstream from the discharge corresponded to the time of the greatest intensity of Marcellus shale gas wastewater disposal, the period from 2009 through 2011.

Section 2.3.3.1 of this document, which discusses impacts on drinking water resources resulting from HVHF, cites the following studies, among others, that document impacts from wastewater treatment plant discharges:

- A 2013 study showed increased levels of barium, strontium, and bromide since 2003 in western Pennsylvania streams known to receive brine effluents from CWTs (Vidic *et al.*, 2013).

- In 2010, the Pittsburgh Water and Sewerage Authority ("Authority") observed a significant increase in total trihalomethanes ("TTHMs"), a class of DBPs, in the Authority's finished water. An investigation by the Authority and the University of Pittsburgh's Swanson School of Engineering found that elevated bromide concentrations in the Allegheny River source water were associated with increased concentrations of TTHMs, especially brominated THMs, in the drinking water, and that industrial wastewater treatment plants treating Marcellus Shale wastewater along with other wastewaters were major contributors of bromide in the raw source water. The study results also indicated that the conventional treatment process used by the Authority for drinking water, which includes enhanced coagulation and secondary sedimentation, was ineffective in removing bromide from the source water. (States *et al.,* 2013).

- A 2015 report by the U.S. EPA determined that the source of nearly all bromide at a public drinking water system intake on the Allegheny River in western Pennsylvania was treated wastewater discharged from CWTs treating oil and gas wastewater. (U.S. EPA, 2015f).

- A study by the U.S. Geological Survey also showed that discharges from oil and gas wastewater treatment plants are sources of DBPs (Hladik *et al.,* 2014). These results are highly relevant to the Delaware River Basin, as DBP formation also has been identified as a concern in public water supplies that use the Delaware River as a source (PWD, 2007). Even with typical treatment, the discharge of HVHF wastewater to surface waters could potentially impact downstream drinking water supplies with the increased risk of DBP formation.

API and MSC both commented that treatment technologies exist that can remove TDS and other constituents in HVHF wastewater, although neither commenter specifically addressed the need to treat radioactive materials to protect water resources. *See,* API, 2018, pp. 11-12; MSC, 2018, pp. 24-26 (tech.). API's consultant ALL outlined available options, including high cost advanced treatment technologies. *See* ALL, 2018, pp. 48-57). EPA has outlined multiple treatment technologies that could be employed, along with costs, capabilities and limitations. These include: chemical precipitation, evaporation/condensation, crystallization, reverse osmosis, biological treatment, and ion exchange. *See,* U.S. EPA, 2018a, Ch. 6. Additional technologies that may be applicable to CWTs have been used or researched for treating oil and gas extraction wastewaters in the laboratory or at non-CWT facilities. These include electrocoagulation, electrodialysis reversal, capacitive deionization, membrane distillation and forward osmosis. *Id.,* p. 6-44. DRBC acknowledges that advanced treatment technologies exist that could be deployed by CWTs.

Chevron Appalachia, LLC indicated that it was the first company to be independently certified by the Center for Responsible Shale Development ("CRSD")[35] and that it maintained that certification through annual audits (Chevron Appalachia, LLC, 2018). The CRSD developed 15 performance standards to reflect leading industry practices. Companies can seek certifications in Air & Climate, Water & Waste, or both, concurrently. While Chevron indicated its support for comments submitted to DRBC by the MSC, neither the MSC nor API recognized the CRSD or its standards in their comments.

CRSD performance standard 1.2 states:

> 1. In order to facilitate comprehensive wastewater management programs that consider environmental, safety, health, and economic factors, Operators may send shale wastewater to a Centralized Waste Treatment facility (CWT) for treatment and discharge if the Operator demonstrates the following conditions are satisfied at the CWT:
>
> a. The CWT has, and is in substantial compliance with, a NPDES discharge permit to treat and directly discharge shale wastewater;
>
> b. The CWT meets or exceeds a CRSD shale wastewater effluent performance standard to be based on current best available technology designed to prevent the discharge of toxic pollutants in toxic amounts;
>
> c. The CWT must use best available technology for all fluids discharged. Best available technology requires a combination of distillation and biological treatment, with the addition of reverse osmosis if CRSD determines based on further analysis that it provides protection necessary to ensure effluent quality. CRSD may authorize the use of different technologies or combinations of technologies that provide equivalent or superior treatment;
>
> d. The CWT adheres to acceptance procedures designed to assure that the wastewater delivered by the Operator is compatible with the other wastes being treated at the facility, treatable by the treatment system, and consistent

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[35] CRSD has described itself as a non-profit organization whose vision is to bring together environmental and gas industry leaders committed to driving continuous innovation and improvement of shale development practices within the Appalachian Basin. The launch date and status of the organization are at present unclear. *Compare, e.g.,* devex.com, which indicates CRSD was founded in 2011, and an item in *Marcellus Drilling News* (MDN) in 2018, reporting that CRSD launched in March of 2013 as the Center for Sustainable Shale Development (CSSD). "Center for Responsible Shale Development has NOT Folded its Tent," *Marcellus Drilling News,* Sept. 11, 2018. https://marcellusdrilling.com/2018/09/center-for-responsible-shale-development-has-folded-its-tent/#:~:text=In%20April%20of%20this%20year,is%20no%20longer%20in%20operation. According to the latter source, CRSD lost its executive director in April of 2018, and its website went dark sometime thereafter. As recently as January 15, 2020, a conference ostensibly mounted by CRSD took place under the banner of the Wilton E. Scott Institute for Energy Innovation at Carnegie Mellon University. *See,* https://www.cmu.edu/energy/crsd-summit.html.

with the specific waste stream the facility was permitted to treat and discharge;

e. The CWT does not indirectly discharge wastewater from a CRSD Operator through a POTW.

(CRSD, 2017, p. 2).

Despite the availability of advanced treatment and best available technology, such as that outlined by the CRSD, a review of 11 "in-scope" CWT facilities (including 8 in Pennsylvania) published by EPA in 2018 indicated that none used the best available technology recommended by the CRSD. *See,* U.S. EPA, 2018b, p. 4-18 (Table 4-9).

EPA's 2018 review of CWTs managing oil and gas extraction wastes examined several data sets and studies to evaluate the effectiveness of current treatment practices. Key among its findings were the following:

- TDS concentrations in effluent and in receiving waters downstream of these CWT facilities are higher than upstream concentrations. Upstream concentrations ranged from 104 to 246 mg/L, while downstream concentrations ranged from 250 mg/L to 5,926 mg/L. The large variability in downstream TDS concentrations occurs because studies report results from sites located at varying distances from the effluent discharge location; two of the studies had sites over 300 meters downstream.

- Conductivity increased by an order of magnitude or more at sites downstream from CWT discharge points compared to upstream sites. Upstream conductivity measurements were below 200 μS/cm, whereas downstream conductivity ranged from 200 to 8,400 μS/cm. In another study, observed conductivity concentrations increase from 290 μS/cm to over 1,300 μS/cm downstream of a CWT facility. Conductivity values greater than 1,000 μS/cm can negatively affect fish assemblages and macroinvertebrate growth and survival (U.S. EPA, 2018b, p. 9-11, citing Kimmel and Argent, 2010; and Johnson *et al*., 2014). thus, these elevated conductivity measurements resulting from CWT discharge are a potential threat to aquatic life.

- Effluent concentrations of chlorides documented in the literature from CWTs treating wastewater from high volume hydraulic fracturing activities can exceed EPA's recommended criteria for protection of aquatic life by many orders of magnitude, ranging from 229 mg/L to 117,625 mg/L. As expected, patterns of higher concentrations of chlorides downstream of CWT facilities were reported as compared to upstream samples.

- Bromide is another component of TDS and, like chloride, the concentrations at sites upstream and downstream of CWT facilities follow a pattern similar to TDS. In regard to CWT facilities, there are more studies reporting bromide concentrations than TDS and chloride because elevated bromide concentrations in source water can increase formation of certain disinfectant byproducts (DBPs) during drinking water treatment processes.

- Metals such as barium, lithium, and strontium can all be components of HVHF wastewater, but few studies of CWTs focus on the impacts of metals on receiving waters. Table 4 below provides the range of concentrations reported in relevant literature cited by EPA (USEPA 2018b) for upstream, effluent, and downstream concentrations for those three metals. Concentrations of barium and strontium in CWT effluent are high enough to elevate downstream concentrations above the respective drinking water Maximum Contaminant Levels (MCLs). In general, Marcellus Shale produced waters tend to contain higher TENORM levels than waters from other formations. When high-salinity CWT effluent mixes with the low-salinity receiving water, radionuclides tend to adsorb onto stream sediments. As presented by EPA (USEPA 2018b, Figure 9-5) the combined Radium (Ra) concentration in effluent averaged 25.1 pCi/L. At 50 m downstream, the mean Ra combined concentration was 11.06 pCi/L, which exceeds the Ra-combined drinking water MCL of 5 pCi/L. At 400 m downstream from the effluent discharge, Ra-combined remained elevated compared to upstream values (0.312 to 0.632 pCi/L), but fell below the MCL to 4.3 pCi/L.

Metal Concentrations Upstream, in CWT Effluent, and Downstream (all units in mg/L)

Metal	Upstream	Effluent	Downstream	MCL
Barium	0.05 to 1.3	0.99 to 27.3	0.15 to 10.9	2.0
Lithium	< 0.025	3.36	0.31 to 0.66	No MCL
Strontium	0.05 to 0.19	42 to 2,981	0.49 to 73	3.0

Table 4: Metal Concentrations in CWT Effluent
Source: USEPA, 2018b (Table 9-2)

- Warner *et al.* (2013a) measured radium concentrations in sediment upstream, downstream, and at the discharge location. They found that radium was substantially reduced in the treated effluent relative to the source produced water (> 90 percent), but 226Ra levels in stream sediments were measured at 15-240 pCi/g at the point of discharge. These sediment concentrations are approximately 200 times greater than radioactivity found in upstream and background sediments (0.6–1.2 pCi/g) and exceed many states' radioactive rules or regulations for unrestricted solid waste disposal, which range from 5-30 pCi/g.

- PADEP analyzed radium concentrations in sediments above and below a CWT facility discharge point. Like Warner *et al*. (2013a), PADEP found elevated Ra-combined levels in the sediment approximately 50m downstream (1.8–2.1 pCi/g) compared to upstream levels (0.8–0.9 pCi/g). Sediment concentrations at the CWT discharge location ranged from 73.9–85.5 pCi/g, over 70 times higher than the upstream concentrations, and above the upper range (30 pCi/g) for states' regulations for solid waste disposal.

(U.S. EPA, 2018b, pp. 9-9–9-17). Additional discussion on risks from radioactive TENORM substances is provided in Section 2.3.2.2, Pollution from Spills.

As noted above, in Pennsylvania about 90 percent of wastewater is recycled or reused and about 10 percent is disposed of using underground injection. For DRBC's response to comments related to underground injection wells, see Section 2.7.3, Earthquakes. For additional discussion of radioactivity in produced water, see the earlier discussion in this Section. Also see, Section 2.3.2.2, Pollution from Spills, under the subheading, "Radioactivity."

Statement of Concern (SC-37)

Commenters have suggested that CWT facilities may, or may not, be effective in treating produced water and wastewaters from HVHF.

Several comments were received from various sources concerning the effectiveness of CWT treatment. The comments included the following paraphrased statements:

- CWT plants should be designed and permitted specifically to receive and treat oil and gas produced water.
- Advances in science and technology should be regularly incorporated into produced water treatment and discharge permitting regimes to continuously work toward more informed, protective standards.
- CWTs should utilize best available technology, including at a minimum a combination of distillation and biological treatment (when necessary reverse osmosis).
- CWTs should follow acceptance procedures to ensure that influent is compatible, treatable, and consistent with the waste stream the facility is permitted to accept and discharge.
- The claim that pollutants in produced water and HVHF wastewater from CWT facilities can be addressed by "treating" to the EPA's Table of Pollutants of Concern and by requiring that water quality standards be met for contaminants that have them, is not supported by the facts. Some contaminants posing significant hazards to human health and flora/fauna (including aquatic life) are not included in EPA's Table, are not subjects of water quality standards or other regulatory limits, have not been characterized sufficiently to allow them to be used in a risk assessment, or remain unidentified because industrial operators consider them trade secrets.

Response (R-37)

Because each natural gas well developed through high volume hydraulic fracturing may generate over 1 million gallons of wastewater per fracturing event, safe methods of recycling and/or treatment must be in place to handle that wastewater. Treatment in CWTs with subsequent discharge of effluent to the waters of the Basin would present significant risks to the receiving waters.

The Commission acknowledges that CWT facilities that receive and treat produced water or other oil and gas wastewater should be designed and approved specifically for this purpose. The Commission also acknowledges that technology changes over time, and CWT treatment should reflect best available technologies.

The Commission concurs in the following key statements included in the executive summary of EPA's detailed 2018 study on the use of CWTs for oil and gas wastewater treatment:

> Oil and gas extraction wastes can contain a variety of constituents, including biochemical oxygen demand (BOD), bromide, chloride, chemical oxygen demand (COD), specific conductivity, sulfate, total dissolved solids (TDS), total suspended solids (TSS), barium, potassium, sodium, strontium, benzene, ethylbenzene, toluene, xylenes, sulfide, gross alpha, gross beta, radium 226, and radium 228.
>
> The pollutants present in and characteristics of oil and gas extraction wastes can vary greatly. Factors that can influence the pollutants contained in and the characteristics of these wastes include the source formation for the oil and gas, the type of drilling and whether stimulation methods are used, the types and quantities of additives used during drilling and well development, and the age of the well.
>
> The range of pollutants present in these wastes typically require the use of a multi-step treatment train to meet discharge standards.
>
> … Some facilities employ multi-step treatment systems specifically designed to remove pollutants commonly found in oil and gas extraction wastes. Other facilities use treatment, such as chemical precipitation, that remove specific pollutants but provide little or no removal of the many other pollutants commonly found in these wastes. As a result, some facilities discharge much greater quantities of pollutants, such as total dissolved solids and chlorides, than others.
>
> Costs for technologies to remove TDS can be high, but nonetheless can be cost-competitive when factors such as transportation to alternate treatment or disposal methods (such as to injection wells) are considered. In addition, technologies (such as evaporation) are available that use waste heat from other industrial sources that, where co-located, can significantly reduce costs of treatment.
>
> EPA approved analytical methods do not exist for many constituents found in oil and gas extraction wastes. In addition, some constituents (such as total dissolved solids) found in oil and gas extraction wastes can interfere with EPA approved analytical methods and significantly affect the ability to detect and quantify the level of some analytes.
>
> The current ELGs [(effluent limitation guidelines)] at 40 CFR Part 437 do not contain limitations for many of the pollutants commonly found in oil and gas

extraction wastes. Many of these pollutants are not included on the current list of priority pollutants.

* * * *

Removal of barium and co-precipitation of radium may create a solid waste management issue at CWT facilities treating oil and gas extraction wastes. More efficient barium removal from the wastewater in the presence of sufficient radium may result in solid waste that exhibits radioactivity at levels that preclude disposal in most landfills. In addition, it is plausible that radioisotopes in wastewater treatment residuals disposed in landfills may subsequently be released to the environment through leachate. The level of radioactivity present in oil and gas extraction wastes is a function of source formation characteristics.

Management of brines and salts produced from technologies such as reverse osmosis, evaporators, and crystallizers may present a solid waste management issue. Disposal of these residuals in landfills has the potential to increase salinity of landfill leachate. Residuals that have marketable characteristics can be produced at CWT facilities. Producing saleable residuals or materials that can be beneficially reused may offset treatment costs. Other management options for these residuals include injection into disposal wells.

CWT effluents may have elevated levels of TDS, halides, metals, and technologically enhanced naturally occurring radioactive materials (TENORM) relative to the receiving streams into which they are discharged dependent upon the treatment technology utilized by the CWT. These elevated concentrations are detectable in samples collected downstream of CWT facility discharge points. The distance over which these elevated concentrations are detectable depends on site-specific factors such as source formation, CWT facility discharge volume, upstream concentrations of constituents, and river flow.

Documented and potential impacts to both aquatic life and human health related to discharges from CWT facilities treating oil and gas extraction wastewater exist due to the prevalence of some pollutants. Levels of pollutants downstream from CWT facility discharges have been reported to exceed applicable thresholds, such as primary and secondary drinking water standards and acute and chronic water quality criteria for protection of aquatic life.

In a number of cases, CWT effluents have been shown to adversely affect downstream aquatic life and, in one case, have been shown to affect survival

> of [the northern] riffleshell mussel [(*Epioblasma torulosa rangiana*)][36], a federally-listed endangered species (e.g., Patnode et al., 2015).
>
> Multiple drinking water intakes are situated downstream of CWTs accepting oil and gas extraction wastewater within distances at which impacts to drinking water from CWTs have previously been identified. Drinking water treatment plants downstream of CWT facilities treating oil and gas extraction wastewater have noted a shift in the composition of DBPs from mostly chlorinated DBPs to mostly brominated DBPs (McTigue et al., 2014), which are more toxic than their chlorinated analogues. These shifts could affect human health from consumption of treated waters.

(U.S. EPA, 2018b, pp. 1-2 – 1-4).

Statement of Concern (SC-38)

Commenters emphasize that if HVHF is permitted in the Delaware Basin, liquid wastes from HVHF, whether treated at a CWT or not, will be spilled or released accidentally or dumped illegally and will result in human health impacts.

Response (R-38)

The Commission agrees that spills, other accidents and illegal releases and discharges of produced water, fracturing fluids or chemicals may result in human health or water resource impacts. For a more detailed response to comments regarding spills of produced water, see Section 2.3.2.2, Pollution from Spills.

Statement of Concern (SC-39)

Treatment plants that handle hydraulic fracturing wastewater routinely exceed effluent limits and face compliance issues for years.

Response (R-39)

There were no specific effluent or compliance data provided with this comment and the DRBC cannot verify the accuracy of the comment. The performance and effectiveness of CWT treatment plants that treat and discharge hydraulic fracturing wastewater are discussed earlier in this section.

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[36] At the request of the US Fish and Wildlife Service, the correct common and scientific names for the northern riffleshell (that were not in the quoted EPA source) are provided for clarity.

Pollution from Wastewater Treatment and Disposal- Summary

After carefully considering the numerous comments the Commission received on pollution from wastewater treatment and disposal associated with high volume hydraulic fracturing, and after evaluating a decade of scientific and technical data and literature on this topic, the Commission finds:

- Risks to surface waters and aquatic life from HVHF and related activities include releases of chemicals, highly contaminated produced water, and other fluids, not only as a result of accidents, but also from inadequate wastewater treatment and improper wastewater disposal and discharge.

- As of 2013, nearly 1.6 billion gallons of wastewater had been generated in the process of extracting natural gas from shale in Pennsylvania. In 2014, 87 percent of this wastewater was recycled and reused in the hydraulic fracturing process. About 10 percent was disposed of at regulated underground injection wells, and 2.3 percent was discharged to surface waters. Produced water from HVHF can be expected to increase over time in Pennsylvania.

- Hydraulic fracturing wastewater (mostly produced water) can contain a variety of constituents, including, among others, biochemical oxygen demand (BOD), bromide, chloride, chemical oxygen demand (COD), specific conductivity, sulfate, total dissolved solids (TDS), total suspended solids (TSS), barium, potassium, sodium, strontium, benzene, ethylbenzene, toluene, xylenes, sulfide, gross alpha, gross beta, radium 226, and radium 228, and chemicals contained in injection fluids and their transformation products.

- U.S. EPA (2018b) describes numerous risks and adverse impacts to water resources from CWT discharges and also finds that analytical methods of detection and effluent guidelines are not available for the full range of constituents in wastewater from HVHF activities.

- Despite the availability of advanced treatment and industry best available technology such as that outlined by the CRSD performance standards, typical industry practice is to treat wastewater to the minimum standards required. EPA's 2018 review of 11 "in-scope" CWT facilities (of which 8 were located in Pennsylvania) found that none used the best available technology recommended by the CRSD.

- Drinking water treatment plants downstream of CWT facilities treating hydraulic fracturing wastewater (mostly produced water) have noted a shift in the composition of DBPs from mostly chlorinated DBPs to predominantly brominated DBPs, which are more toxic than their chlorinated analogues. These shifts could affect human health from consumption of treated waters.

- The Commission agrees with and relies on the EPA's understanding and interpretation of the peer-reviewed scientific research published through 2016 and the EPA's conclusion that hydraulic fracturing activities can impact drinking water resources.

- After publication of U.S. EPA's 2016 report on the impacts of HVHF on drinking water resources in the United States, additional research has reinforced EPA's conclusions and provided additional compelling evidence that HVHF can cause adverse impacts to water resources. The 2018 EPA report on CWT facilities concluded that discharges of treated effluent from CWTs accepting oil and gas wastewater have caused environmental impacts on water quality, drinking water, and aquatic life.

In view of the above, the Commission has determined that a risk of significant impacts on Basin waters resulting from the treatment and disposal of HVHF wastewater exists. The Commission has further determined that this risk could be effectively managed through regulation if it were the only such risk associated with HVHF. However, in light of the other effects discussed in this document, the impacts associated with treatment and disposal of HVHF wastewater contribute to the totality of the risks and impacts that accompany HVHF and related activities. The potential for adverse impacts to water resources associated with the treatment and disposal of HVHF wastewater, combined with the totality of the risks, vulnerabilities, impacts, and uncertainties discussed throughout this comment and response document, supports the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.2.5 Landscape Changes

Statement of Concern (SC-40)

Commenters raised concerns about the placement of natural gas well pads and ancillary infrastructure, such as roads, water lines, gas gathering lines and compressor stations, and their potential impacts to water resources. Specifically:

- In the absence of planning, the haphazard placement of gas wells and their associated infrastructure has caused additional water quality impacts.
- At a minimum, if allowed, any well pads should be sited as far away as possible from the river corridor boundary to still be able to horizontally drill beneath the river corridor.
- Durham Township (consisting of only 9 square miles) has received the right under Act 13 to determine where well pads can be placed, such as in the Industrial Zone. However, the Township's Industrial Zone is adjacent to the Delaware River and Cooks Creek (an Exceptional Value stream).

Response (R-40)

The DRBC acknowledges the concerns raised by commenters surrounding the siting of well pads and ancillary infrastructure relative to streams and other water resources. DRBC agrees that well pad placement near streams may enhance the risk of water quality impacts to these streams. Likewise, construction of well pads in water recharge locations or far from existing roadways may cause a loss of ecosystem services provided by natural features disturbed during construction. Even with setback and other restrictions, risks to groundwater and surface water resources would remain.

Because the final regulations prohibit HVHF in the Delaware River Basin, no adverse impacts to water resources will occur as a result of the siting of wells, well pads and ancillary infrastructure.

Statement of Concern (SC-41)

Due to changes in the fracking process, the number and length of wells is growing substantially throughout the region, thus increasing both the size of well pads and the consequent environmental impacts. The trend of impacts today is more than double the figure of just several years ago (destruction of 8.8 acres per well pad in 2011, with 30 acres of forest impacts due to edge effects).

Commenter notes that land disturbance is an unavoidable and dramatic part of the fracking process, which transforms a natural landscape into an industrial one. This includes, among other things, well pads that generally take up 1-3 hectares to accommodate all support equipment, access roads, appurtenant structures, and collection/ transmission pipelines.

Response (R-41)

The DRBC acknowledges the concerns raised by commenters regarding the land disturbances associated with well pads and ancillary infrastructure, including access roads, appurtenant structures and collection/ transmission pipelines.

A report provided by the American Petroleum Institute stated, "the average surface area impacted as a result of constructing a multipad with road and utility access, and processing and water management areas is approximately 11.5 to 15 acres (ALL Consulting, 2018). USGS has found that approximately 4.1 hectares (10.3 acres) were disturbed for each Marcellus Shale well pad in Bradford County, Pennsylvania (Slonecker *et al.,* 2012, p. 21) (see Table 5), and that approximately 3.1 hectares (7.7 acres) were disturbed for each Marcellus Shale well pad in Susquehanna County, Pennsylvania (Slonecker *et al.,* 2013, p. 19).

Because the final regulations prohibit HVHF in the Delaware River Basin, no adverse impacts to water resources will occur as a result of the siting of wells, well pads and ancillary infrastructure.

Amount of landscape disturbance for natural gas extraction development and infrastructure based on disturbance type. MS and non-MS sites refer to Marcellus Shale and non-Marcellus Shale sites, respectively.

Land cover update	Count	Site only hectares	Footprint disturbed hectares	Road kilometers	Pipeline kilometers	Hectares per site	Disturbed hectares per site	Road kilometers per site
Bradford County (300,991.7 hectares)								
All infrastructure	642	1,300.3	1,506.3	74.82	178.4	2.0	2.3	0.2
All sites and roads	262	742.4		73.7				
MS sites and roads	210	616.7	865.8	66.1		3.0	4.1	0.3
non-MS sites and roads	19	49.2	58.4	5.8		2.5	3.1	0.3
Other infrastructure/ unpermitted sites and roads	44	116.5	143.0	5.5		2.6	3.2	0.2
Dual sites	11	39.9						
Pipelines	97	432.7	450.3	77.4	178.4			
Impoundments (>0.40 ha)	561	1,203.7				2.1		
Impoundments (<0.40 ha)	121	22.7				0.2		

Table 5: Landscape disturbance for natural gas extraction.
Source: Slonecker et al. 2012, Table 1.

Statement of Concern (SC-42)

Commenters noted that advances in horizontal drilling and hydraulic fracturing have led to the drilling of longer wellbores and the construction of more wells per pad, thus reducing the number but increasing the size of well pads. They asserted:

- In 2014, an average of five wells were developed per pad in the Marcellus;
- The recent apparent industry trend is for 10-20 wells per pad, with plans for up to 40 per pad.

The commenters said these larger sites mean fewer well pads in total, and note that from a 10-acre surface area, natural gas can theoretically be extracted from the subsurface of an area nearly the size of a city (35,000 acres).

Response (R-42)

The DRBC acknowledges that in areas outside of the Basin lateral wellbores are being drilled to longer distances. The DRBC also acknowledges that in areas outside of the Basin the number of wells per pad is increasing, which results in larger well pads (ALL Consulting, 2018, p. 41).

The DRBC acknowledges that in areas outside of the Basin, larger well pads and longer laterals may make possible the extraction of natural gas from an area that might have required multiple well pads several years ago. Finally, the DRBC recognizes that as the length of laterals increases, the volume of fracturing fluids used to stimulate shale formations through the lateral likewise increases as does the volume of flowback water which must be captured, stored and managed.

Statement of Concern (SC-43)

Commenters expressed serious concerns about the impact to forests (including fragmentation, water quality, and wildlife/biota/biodiversity impacts) associated with the construction, development and operation of HVHF natural gas well sites, which are paraphrased as follows:

- Estimates for each drilling installation assume an ecological edge effect of 330 feet extending into intact forest from cleared areas, resulting in 30 acres of forest affected. Forest destruction and fragmentation in turn destroys the ability of the forest ecosystem to capture, clean, and infiltrate precipitation, sequester carbon, while reducing biodiversity, encouraging invasive species, and destroying vital habitat.

- Approximately 85 percent of the lands underlain by Marcellus Shale in the DRB are forested. As a result, the Delaware River watershed would suffer from the extensive forest fragmentation created by oil and gas operations in the Basin.

- Gas well development transforms the land to an industrial landscape, resulting in destruction of vegetation (8.8 acres per well pad in 2011 with 30 acres of forest impacts due to edge effects), soil compaction and destruction of the natural land contours, alterations to watershed drainage patterns, and hydrologically connected systems such as wetlands and vernal pools. Habitats and complex ecosystems are disrupted or lost.

- The loss of forested land increases the cost of providing safe drinking water, especially to downstream urban areas in the Delaware River Watershed. Every well drilled will require additional transmission lines that will remove more acres of timber and prohibit the use of that land for anything but growing grass.

- Scientific literature explains the clear link between forests and water quality, verifying that reductions in forest cover correlate with negative changes in water chemistry, such as increased levels of nitrogen, phosphorus, sodium, chlorides and sulfates as well as reduced levels of macroinvertebrate diversity.

- A U.S. Forest Service report acknowledges the documented benefits of forest ecosystem services to water purification, the loss of which can degrade water quality.

- New access roads, well pads, and pipelines would harm Pennsylvania's ecologically vital and unique Pocono plateau forests.

Response (R-43)

The DRBC acknowledges that parts of the DRB underlain by the Marcellus and Utica Shales have significant forest cover. In general, landscapes with high percentages of forest cover correlate strongly with high quality water resource features (Edwards *et al.,* 2015). The Open Space Institute (OSI) performed a literature review of forest cover and water quality. Their review found that forest cover has clearly established water quality benefits at many scales. OSI found that watersheds with more land in forest tend to have better water quality. OSI also suggests that water quality begins to deteriorate when forest cover falls below 60-90% of the catchment area, depending on context (Morse et al., 2018, p. 9).

Using time-sequenced aerial photography, the USGS has conducted detailed mapping studies of the actual extent of surface disturbance from oil and gas development in the Marcellus Shale in Bradford County, Pennsylvania (proximate to the DRB) (*see,* Slonecker *et al.,* 2012). The USGS determined that both forest and agriculture land cover types were cleared for oil and gas development (Slonecker *et al.,* 2012, p. 23) (see Table 6). The Nature Conservancy performed an assessment of the impacts to forest resources from high volume hydraulic fracturing for Tioga County, New York and found that natural gas development would fragment as well as reduce the county's remaining forest habitat. TNC found that the construction of well pads, roads, pipelines and other infrastructure associated with gas drilling would cause short- and long-term forest loss, conversion, and fragmentation of forest habitats. In addition to those direct habitat impacts, TNC concluded, natural gas development would also negatively impact the size, shape, and connectivity of the remaining habitat. Species that rely on continuous unfragmented forest habitat for movement, breeding, foraging and dispersal would be impacted (Lee *et al.,* 2011).

Percent land cover presented in descending order for each county. Change in percent forest is shown in bold. MS and non-MS sites refer to Marcellus Shale and non-Marcellus Shale sites, respectively.

Land cover	Original land cover	Updated with all infrastructure	Change	Updated with MS sites and roads	Change	Updated with non-MS sites and roads	Change	Updated with other infrastructure	Change	Updated with pipelines	Change
Bradford County											
Forest	56.12	56.01	-0.12	56.06	-0.06	56.12	-0.01	56.11	-0.01	56.07	-0.05
Agriculture	35.47	35.20	-0.27	35.31	-0.16	35.46	-0.01	35.44	-0.03	35.38	-0.09
Developed	4.96	4.95	-0.01	4.96	0.00	4.96	0.00	4.96	0.00	4.96	-0.01
Grassland - herbaceous	0.16	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.00
Water	0.96	0.96	0.00	0.96	0.00	0.96	0.00	0.96	0.00	0.96	0.00
Barren	0.11	0.11	0.00	0.11	0.00	0.11	0.00	0.11	0.00	0.11	0.00
Wetlands	0.75	0.75	0.00	0.75	0.00	0.75	0.00	0.75	0.00	0.75	0.00
Scrub - shrub	1.46	1.45	-0.01	1.45	-0.01	1.46	0.00	1.46	0.00	1.46	0.00
Gas extraction disturbance		0.41	0.41	0.23	0.23	0.02	0.02	0.04	0.04	0.15	0.15

Table 6: Types of landscape disturbances from gas extraction
Source: Slonecker et al. 2012, Table 2

New York State's Final SGEIS for Horizontal Drilling and High volume Hydraulic Fracturing found that forest parcellation and fragmentation due to HVHF would likely result in the future loss of large contiguous forested areas (NYSDEC, 2015a, p.6-76). Forest complexes provide substantial ecological, economic, and social benefits (water quality protection, clean air, flood protection, pollination, pest predation, wildlife habitat and diversity, recreational opportunities, etc.). Large, contiguous forest patches are especially valuable because they sustain wide-ranging forest species and provide more habitat for forest interior species. They are also more resistant to the spread of invasive species, suffer less tree damage from wind and ice storms, and provide more ecosystem services – from carbon storage to water filtration – than small patches.

The USGS noted that glacial and peri-glacial impacts to landscapes are particularly evident in the Pennsylvania portion of the DRB. These impacts include the deposition of glacial deposits such as till (which generally have poor drainage) and the formation of glacial features such as moraines, kames, and stratified drift (that are sensitive to surface disturbances). Additional impacts of glaciation include the disruption of pre-glacial drainage systems, resulting in the formation of non-integrated (internal/deranged) stream networks that commonly result in the formation of swamps, peat bogs, and large boulder fields (as in Tobyhanna, PA). These physiographic features contain ecosystems that are sensitive to surface disturbances. More significantly, these landforms are "out of equilibrium" with the current weathering environment and climate in the region. As such, these features are especially vulnerable to land disturbances and changes such as those associated with the clearing of trees, construction of roads, drill pads, compressor stations, storage yards, and pipelines (USGS, 2018, p.5).

Because the final regulations prohibit HVHF in the Delaware River Basin, no adverse impacts to forest cover and other landscape features, including unique regional habitats, will occur as a result of the siting of wells, well pads and ancillary infrastructure to service those wells.

Statement of Concern (SC-44)

Commenter suggests there is no need for further regulation of HVHF activities regarding forested areas, since Wayne County, PA has added nearly 45,000 acres of forest since 1959, which is more than what would be removed by natural gas development.

Response (R-44)

The change in forest cover in Wayne County, PA since 1959 does not eliminate the Commission's obligation to protect and conserve the Basin's water resources today and into the future. In addition, re-forestation in one area or sub-watershed would not necessarily mitigate the loss of forested areas across sub-watersheds overlying the Marcellus and Utica Shales throughout the Basin if HVHF were to be permitted.

Statement of Concern (SC-45)

- Commenter asks whether there are regulations governing the restoration of disturbed area as a result of and following HVHF activities.
- Commenter believes the estimates of total area disturbed by HVHF activities are not accurate, since they do not account for restoration activities once operations are complete. At the completion of restoration activities, only about 3.5 to 5 acres per pad site remain altered.
- Restoration efforts reduce the amount of acreage impacted by fracking operations. Altered acreage following restoration over the 10-year development period ranges from 400 acres for a 5-well per pad scenario to only 200 acres for a 10+ wells per pad scenario.

Response (R-45)

The DRBC acknowledges that a portion of the total land impact from HVHF development activities is mitigated by the restoration of temporary and short-term disturbances. The footprint of disturbance at a single well pad may be reduced over time. The total disturbance throughout the Basin may vary depending on the rate of construction of new well pads and infrastructure. Because the final regulations prohibit HVHF in the Delaware River Basin, no adverse impacts to forest cover and other landscape features, including unique regional habitats, will occur as a result of the siting of wells, well pads and ancillary infrastructure.

Statement of Concern (SC-46)

There are no detailed maps of regulated wetlands in the DRB. Existing National Wetland Inventory maps show the general location of wetlands recognizable from aerial photographs, but omit many forested wetlands, which are a common feature of the subwatersheds draining to waters the Commission has designated as Special Protection Waters. These forested wetlands offer special habitat values over and above other kinds of wetlands in this biome.

Wetlands and associated habitats are characterized by hydrologic conditions and are sensitive to development activities that result in changes in water volumes, timing of flows, and discharges of various pollutants. Wetlands have been documented to have been degraded by oil and gas development. Thus, there is substantial potential for destruction and loss of wetlands if fracking were to occur in the DRB.

Several studies document the limited success of wetland mitigation. Once a natural system such as a wetland is damaged or destroyed, it is very difficult to restore that resource's full function or to replace those lost ecosystem functions with another. The far better policy is to prevent the damage rather than try to repair or replace after the intact natural system is diminished.

Response (R-46)

It is the policy of the DRBC to support the preservation and protection of wetlands in accordance with Section 2.350.2 of the Delaware River Basin Water Code. The Commission's rules relating to wetlands provide that DRBC will rely on reviews performed by federal and state agencies for projects involving the alteration of fewer than 25 acres of wetlands, except in instances where the state or federal agency's final action may not adequately reflect the Commission's policy regarding wetlands.

The removal or degradation of wetlands can adversely impact their valuable ecosystems functions. DRBC's definition of "wetlands" refers to "those areas which are inundated by surface or ground water with a frequency sufficient to support a prevalence of vegetative or aquatic life that requires saturated soil conditions for growth and reproduction or are delineated as wetlands by a signatory state" (Water Code § 2.350.1). The DRBC recognizes the potential degradation of wetlands as one of the risks to water resources posed by natural gas development activities. Additional discussion of impacts to wetlands is provided in Section 2.3.3.4 of this document.

Statement of Concern (SC-47)

The current average surface area impacted by constructing a multi-well pad with road and utility access, and processing and water management areas is approximately 11.5 to 15 acres. Cumulative projected land disturbance impacts over the next 10 years, under two differing scenarios, are as follows:

- 5-wells per pad: eight (8) pads developed/year for an estimated 120 acres annually (8 pads x 15 acres each) = 1,200 acres altered (1.87 sq. miles)

- 10+ wells per pad: eight (8) pads the first year with additional wells added to existing pads; the number of new pads per year would decrease over subsequent years resulting in only 40 pads = 600 acres altered (0.94 sq. miles)

Statement of Concern (SC-48)

- Commenter asserts that upwards of 1¼ million acres of new impervious surface cover overlying the Marcellus Shale formation can be expected from gas well development. This has direct adverse impacts on water quality and water supplies, the maintenance of biological life in streams, and causes increased polluted stormwater runoff, sedimentation and flooding to waterways.

- The Commenter cites an analysis conducted by CNA for the Delaware Riverkeeper Network, which projected the total land area disturbance in 3 upper DRB counties through the completion of gas development to be 18-26 square miles. This "fracking footprint," or cumulative projected harm, equates to 570-840 Walmart Supercenters (including parking lots).

Response (R-47 and R-48)

The DRBC did not attempt to perform a full oil and gas development analysis of the Basin areas underlain by the Marcellus and Utica formations. The formation types and their depth, orientation, deformation, and thermal maturity in the DRB have not been well studied or mapped. Most of the existing geologic mapping lacks the data necessary to accurately delineate the deep subsurface structure in the region and, accordingly, identify likely locations and spacing of well pads, wells, and the orientation of laterals. In addition, because the DRB has not been widely developed for unconventional oil and gas, applicable data are sparse. In summary, data to develop estimates of the per-well, per-pad, or associated infrastructure landscape impacts are insufficient to provide an estimate of total acreage that would be impacted by a full oil and gas development scenario. As discussed in Section 2.6.6, Economic Impacts, we suggest the development assumptions prepared by CNA are seriously flawed.

Landscape Changes - Summary

In considering the numerous comments the Commission received on the potential for water resources impacts to accompany landscape changes in the Delaware River Basin if high volume hydraulic fracturing were permitted in the Basin, the Commission has evaluated a decade of scientific and technical data and literature and finds:

- Where HVHF is performed, well bores and laterals are being drilled to longer distances, approaching several miles.
- Also, where HVHF is performed, the number of wells per pad is increasing, which may result in larger well pads.
- The use of larger HVHF well pads with longer laterals allows producers to extract natural gas from the same area with fewer well pads than would have been required several years ago. The volume of fracturing fluids used and flowback water captured, stored and managed increases with lateral length.
- Wetland areas within the Delaware River Basin would likely be adversely impacted by the ancillary infrastructure (e.g. pipelines, roads, compressor stations) associated with HVHF activities.
- Floodplain areas within the Basin would likely be adversely impacted by the ancillary infrastructure (e.g. pipelines and roads) associated with HVHF activities.
- Portions of the DRB underlain by Marcellus and Utica Shale have significant forest cover.
- The unique physiographic features of the portion of the Delaware River Basin underlain by the Marcellus and Utica Shales include ecosystems that are sensitive to surface disturbances.
- In general, landscapes with high percentages of forest cover correlate strongly with high quality water resources (Edwards *et al.,* 2015).
- Forest and agricultural land are the prominent land cover types impacted by HVHF development in Pennsylvania.
- HVHF development in the DRB would fragment as well as reduce forest cover.
- Forest complexes provide substantial ecological, economic, and social benefits (water quality protection, clean air, flood protection, pollination, pest predation, wildlife habitat and diversity, and recreational opportunities).
- The threshold band for the percentage of forest cover a catchment requires for good water quality is 60-90 percent.

On the basis of its review, the Commission has determined that the risk to water resources associated with the landscape changes that accompany HVHF could be effectively managed through regulation if this were the only such risk associated with HVHF. However, in light of the other risks and impacts discussed in this document, the risks to water resources associated with landscape changes contribute to the totality of the water resources risks and impacts that accompany HVHF and related activities. The potential for adverse impacts to water resources associated with landscape changes, combined with the totality of the risks, vulnerabilities, impacts, and uncertainties discussed throughout this comment and response document, supports the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.3 Significant Impacts to Water Resources and their Uses

To effectuate its Comprehensive Plan, DRBC seeks to preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. This Section responds to comments regarding the impacts of HVHF activities to water resources and their uses. The risks to water resources posed by HVHF activities and the potential impacts of these activities on water resources have been extensively discussed and documented in the literature (Vengosh *et al.,* 2014; Vengosh *et al.,* 2013; Entrekin *et al.,* 2011), and these topics are the subject of recent and continuing research. Responses to comments on potential impacts of HVHF and related activities to drinking water resources, other water uses, surface waters and aquatic life, groundwater, wetlands, and flood plains are presented in respective sections below.

Assessing adverse impacts from hydraulic fracturing and related activities on water resources is a complex process. Impacts can result from any part of the hydraulic fracturing water cycle, and effects can be immediate, near-term, or delayed. Impacts may be transient or long-term, often depending on the characteristics of the affected water resource. Effects may be close to the HVHF activity or some distance away. Some types of impacts may be caused by certain HVHF operations but not others. The presence of naturally occurring methane or other water-quality constituents, or contaminants from sources not related to HVHF activities may mask water-quality impacts from HVHF activities. The complexities of the impacts also permeate the scientific process of understanding and assessing them. Scientific studies may address some aspects of this complexity while ignoring others. For example, a study designed to evaluate potential impacts close to HVHF activity may not detect impacts occurring at a distance. A study designed to evaluate impacts immediately following HVHF activity may not detect impacts that were delayed. A study designed to determine if regional water quality has been impacted on a widespread basis by dispersed HVHF activities may not detect the occurrence of severe but isolated "hot spots" of HVHF impact. Impacts to water resources from human activities other than HVHF can mask impacts from HVHF and confound our ability to attribute the cause of impacts. These examples highlight the importance of understanding the limitations of individual scientific studies when evaluating the weight of the evidence on a particular type of impact.

Most of the scientific studies cited in this document relied on observational data representing a finite sample of environmental conditions. Many studies, using limited available samples of observations, have found evidence of impacts of HVHF and HVHF-related activities to water resources. Other studies, using different, limited samples of observations, have not found evidence of impacts. Although reconciling apparent contradictory findings can be challenging, the Commission employed a weight of evidence approach in evaluating the science to achieve this goal.

In DRBC's responses that involve the findings of research reports and publications, the author affiliations and the identity of funding organizations are noted or clarified in cases in which author affiliation or funding organization involvement is unclear, or in which research findings are disputed. These relationships are especially important when an author's affiliation and/or funding source is a stakeholder group with a vested interest in the study outcome. Financial relationships can influence research outcomes in a variety of ways (Resnick and Elliott, 2013). These notations and clarifications help in the consideration of the risk of bias in the research.

2.3.3.1 Drinking Water Resources

Many commenters expressed views about impacts specific to drinking water resources resulting from HVHF activities. They expressed concern that hydraulic fracturing activities would impact sources of public or private drinking water supplies by contamination, degradation, or diminution. These comments were expressed in 13 resolutions of Basin municipalities; in a petition by 41 organizations representing sportsmen and women; in letters by more than 13,000 individual members of the public; and in 13 petitions signed by a total of more than 39,000 individuals. Many other commenters suggested that the potential for impacts to drinking water resources is minimal or that the DRBC's proposed regulations are unnecessary for the protection of drinking water resources. These comments were expressed in submissions from five industry groups; a natural gas advocate; supervisors of a township; a county department of planning; and 1,288 individuals.

Statement of Concern (SC-49)

Representative paraphrased examples from commenters who generally support Section 440.3 of the draft rule (and generally oppose hydraulic fracturing) in the Delaware River Basin:

- The long-term threats to drinking water supplies are not fully known and the risks are too great. The DRB provides sources of drinking water for 15-17 million people (This estimate is from commenters. The DRBC estimate is 13.3 million people), including New York City and Philadelphia, and the proposed DRBC regulatory requirements governing hydraulic fracturing are insufficient to protect these resources.

- The safety of our drinking water must not be put at risk by allowing hydraulic fracturing and the release of toxic wastewater into the Delaware watershed. This can occur from negligence, accidents and spills, and even permitted discharges.

- Hydraulic fracturing wastewater is dangerous because it contains over 600 different toxic chemicals, many of them carcinogenic, which could lead to pollution and contaminated drinking water, especially for downstream communities. The risks of hydraulic fracturing to the drinkable water supply have been shown to be high.

- EPA confirmed specific instances of water contamination caused by drilling and hydraulic fracturing-related activities and identified the various pathways by which this contamination has occurred. These pathways include spills, the discharge of hydraulic fracturing waste into rivers and streams, and underground migration of chemicals, including gas into drinking water wells.

- The New York City Department of Environmental Protection commented that it conducted a study that determined, based on the best available science and the current state of technology, that high volume hydraulic fracturing cannot safely be conducted in the New York City watershed.

- The Philadelphia Water Department commented that any regulations related to hydraulic fracturing in the Delaware River Basin should preserve the quality and quantity of the drinking water supply for current and future generations. The Philadelphia Water Department fully supports the ban on hydraulic fracturing in the draft regulations.

- Some constituents in produced waters from natural gas development, which are considered "emerging contaminants," are known to pose serious human health risks and have ecosystem/environmental impacts. These substances pose unacceptable risks because they may be released into the environment without detection or any requirement for monitoring, detection, or treatment. Moreover, some of these substances, such as endocrine disruptors (EDCs), are potentially dangerous at extremely low concentrations, and the full effects on public health and wildlife populations are not currently known.

- The EPA's 2016 study of hydraulic fracturing concludes that there is scientific evidence that hydraulic fracturing activities can impact drinking water resources under some circumstances, and cites the cases of Dimock, PA, Pavillion, WY, and Parker County, TX.

Representative examples from commenters who generally oppose Section 440.3 of the draft rule (and generally support hydraulic fracturing) in the Delaware River Basin:

- Review of available approved dockets from the DRBC website indicates that public water supply intakes on the Delaware River are rare in Special Protection Waters ("SPWs") and most are more than 100 hundred river miles downstream of Wayne and Pike Counties, the area of likely natural gas development and associated produced water treatment. The concern over potential discharge impacts affecting down-stream public drinking water supply withdrawals is nonexistent.

- Government data and scientific research make it clear that our commitment to safety is paying off. Hydraulic fracturing is safe and does not contaminate drinking water. Given this evidence, your proposed rule goes too far.

- Hydraulic fracturing itself has not polluted water supplies.

- A report by TAMEST (2017) supports the EPA's original fact-based assertion that hydraulic fracturing is not a significant threat to drinking water supplies, concluding, "Direct migration of contaminants from targeted injection zones is highly unlikely to lead to contamination of potential drinking water aquifers."

- Approximately 99.5 percent of the contents of most hydraulic fracturing fluid systems are well-known and widely disclosed: water (90 percent by volume) and a proppant (typically sand or other non-toxic material, which constitutes 9.5 percent by volume). The substances that are most commonly found in the additional 0.5 percent of hydraulic fracturing fluid systems are also commonly found in food, cosmetics, detergents and other household products (GWPC and ALL Consulting, 2009, p. 63).

- Waste from oil and natural gas drilling and production activities are managed in accordance with state and federal environmental laws and numerous industry recommended practices and standards.

- Effluent from available wastewater treatment technologies can range from clean water that meets drinking water standards to brines that can be recycled for various uses, including for fracturing additional wells, to solids that can be disposed of or recycled easily.

Response (R-49)

DRBC acknowledges the comments highlighting the potential risks of HVHF activities that could impact water resources that serve as sources of drinking water for a large population. The Commission appreciates the expression of support for the Final Regulations as a rational and responsible approach to protecting water resources of the Delaware River Basin. Comments minimizing the risks to drinking water resources are not consistent with the weight of the scientific evidence, the record of industry safety and compliance with regulations, nor the recognition of other factors that contribute to the risks to drinking water resources. The discussion below elaborates on these points.

The Commission's authority, established by the Delaware River Basin Compact, is discussed in Section 2.1.1 of this document. The Compact requires the Commission to adopt a Comprehensive Plan to manage the Basin's water resources. Details about the Delaware River Basin Compact and the Comprehensive Plan are presented in Section 1.9 of this document.

Risks to Drinking Water Resources

The water resources of the Delaware River Basin, serving over 13 million people, are described generally in Section 1.6 of this document. Shale gas development through HVHF is an industrial activity that poses risks particular to this industry and that may be exacerbated by the Basin's unique geographic, geologic, hydrologic, and regulatory setting. As explained in greater detail below, and in other sections of this document, the activities and materials associated with unconventional gas development through HVHF can result in, and have resulted in, significant impacts to sources of drinking water. Furthermore, the long-term impacts of this relatively young industry on drinking water resources are not fully understood. The 2016 EPA assessment report describes in detail the activities of the five stages of the hydraulic fracturing water cycle that involve water and the risks specific to drinking water resources that are encountered at each stage. These stages include water acquisition, chemical mixing, well injection, produced water handling, and wastewater disposal and reuse (U.S. EPA, 2016a, p. ES-9). The section of the EPA report on the well injection stage includes an overview of well construction, mechanical integrity issues, and the implications of the loss of mechanical integrity as wells age. Risks to drinking water resources at each stage of the hydraulic fracturing water cycle were identified by the EPA, and are noted in Table 7, adapted from the EPA report:

Stage of Hydraulic Fracturing	Risks to Drinking Water Resources	Potential Contaminant Transport Pathways
Water acquisition	• Excessive aquifer drawdown and reduced well yield; • Stream depletion	N/A
Chemical mixing	• Spills, leaks, and other releases	• Surface flow to surface water • Infiltration and subsurface flow to groundwater • Combinations of surface flow and subsurface flow
Well injection (includes activities associated with well construction, stimulation, production, and post-production)	• Migration of drilling fluids during construction; • Migration of gas and/or fluids from target formation to aquifers or streams; • Migration of gas from non-target formations to aquifers or streams; • Surface release of fluids (Blowouts, other equipment failures, interborehole communications)	• Subsurface flow • Well borehole resulting from well failure, inadequate well construction, and/or well deterioration with age • Surface flow
Produced water handling	• Spills, leaks, and other releases	• Surface flow to surface water • Infiltration and subsurface flow to groundwater • Combinations of surface flow and subsurface flow
Wastewater disposal and reuse	• Inadequate treatment • Improper storage or disposal • Reuse for roadway de-icing or dust control	• Surface water discharge • Surface water runoff • Infiltration or subsurface discharge and subsurface migration

Stages of the hydraulic fracturing water cycle, associated risks, and potential contaminant transport pathways. Source: U.S. EPA, 2016a.

Table 7: Risks to Drinking Water Resources at Each Stage of the Hydraulic Fracturing Water Cycle

The risks and concerns identified in the 2016 EPA Assessment Report are recognized by the states of New York, a portion of which lies within the Delaware River Basin, and Maryland, which adjoins the Delaware River Basin (and has a small land area within the Basin), both of which have elected to prohibit high volume hydraulic fracturing within their jurisdictions.

Given the potential for natural gas development expansion into the Basin, the DRBC Commissioners sought to formulate a water resource management policy that was consistent with the agency's authority and obligations under the Delaware River Basin Compact. Based on a review of numerous scientific studies, reports and associated literature over the past nearly ten years, and through consultation among the representatives of the Compact's signatories and their expert agencies, the Commission recognizes the inherent, known risks associated with hydraulic fracturing as well as the considerable uncertainty that remains regarding long-term impacts to drinking water resources.

In total, over 13 million people rely upon the waters of the Basin for drinking water and other uses that need to be protected. While not all of the 13 million people using Basin water would be impacted if hydraulic fracturing activities occurred, the location of the areas of potential production are aligned with the sensitive headwaters of the Basin in Pennsylvania and New York upstream of many drinking water sources and users. The risks to drinking water resources posed by HVHF and HVHF-related activities are substantial. An assessment of the risk posed by HVHF to the New York City reservoir watershed, which is partly in the Delaware River Basin, concluded:

> Development of natural gas resources using current technologies thus presents potential risks to public health and would be expected to compromise the City's ability to protect the watershed and the continued, cost-effective provision of a high-purity water supply.

(NYCDEP, 2009, p. ES-3).

The Commission agrees with this assessment and with the comments expressed by the Philadelphia Water Department about the purpose and function of regulations in the Delaware River Basin to preserve the quality and quantity of the drinking water supply for current and future generations. The regulations prohibit high volume hydraulic fracturing within the Basin (*see* 18 C.F.R. § 440.3(a)) and are thereby consistent with this purpose. The regulations protect and conserve the water resources of the Delaware River Basin and control future pollution in the waters of the Basin.

The Commission recognizes that materials used in and produced by HVHF activities can be transported to drinking water resources during different HVHF processes and through different pathways. The Commission understands that many chemicals, additives, and agents are used during high volume hydraulic fracturing and that large volumes of complex mixtures of residual wastes are generated. Chemicals used in HVHF and related activities are discussed in Section 2.3.2.2, Pollution from Spills. Toxicity is known for only 11 percent of the compounds used in hydraulic fracturing fluids and detected in HVHF produced waters, and many of these chemicals are known to be hazardous to human health (U.S. EPA, 2016a, p. 9-1). Health effects associated with chronic oral exposure to these chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity. However, the toxicity of the majority of chemicals that the EPA has identified as being associated with HVHF activity is unknown (U.S. EPA, 2016a, p. ES-43). With the limited availability of toxicity metrics, risk assessment is difficult, and the full potential for impacts to drinking water resources cannot be adequately assessed.

The potential for transport of these materials, as well as natural gas, to the surface waters and groundwater of the Basin are a concern. Responses to comments on the specific risks related to water acquisition are presented in Section 2.3.2.1, Water Use. Responses to comments on the risks related to chemical mixing and produced water handling are presented in Section 2.3.2.2, Pollution from Spills. Responses to comments on the risks related to well injection are presented in Section 2.3.2.3, Pollution from Fluid Migration. Responses to comments on the risks related to wastewater disposal and reuse are presented in Section 2.3.2.4, Pollution from Wastewater Handling and Disposal. Additional details on this last topic as it relates to impacts to sources of drinking water are presented below.

Impacts to drinking water resources from HVHF wastewater disposal: The percentage of HVHF wastewater managed through disposal rather than recycling is currently a small percentage of the overall volume of wastewater generated in Pennsylvania by unconventional wells. Although recycling of HVHF wastewater is widely practiced in Pennsylvania, excess produced water needs to be managed by other means. In the future, there could be an increasing trend in excess wastewater generation as more wells are in the production phase and fewer wells are being fractured. This would translate to an increasing trend in excess produced water in need of disposal by deep well injection, centralized treatment with surface water discharge, or by another reuse, such as road spreading (were road spreading of hydraulic fracturing wastewater to be allowed). If HVHF were to occur in the Basin, this pattern of increasing wastewater generation might repeat itself, resulting in large volumes of wastewater requiring disposal through means other than recycling. There are few deep well injection facilities operating in Pennsylvania. A high percentage of the nonrecycled flowback and produced water from Pennsylvania is being shipped by truck or rail to the many commercial injection well facilities operating in Ohio and West Virginia (SAFERPA, 2015). Responses to comments regarding deep well injection are presented in Section 2.7.6, Underground Injection Wells for Disposal of HVHF Wastewater.

The potential for impacts from the discharge of treated HVHF wastewaters to surface waters is a concern as it relates to multiple designated uses of surface waters, including as a source of drinking water. The risks from pollution from HVHF wastewater handling and disposal, described in Section 2.3.2.4, resulted in a substantial impact to drinking water in western Pennsylvania before regulations were updated to address the issue. Monitoring for effects of HVHF have included parameters such as barium, strontium, and bromide, which are highly specific signatures of produced waters from oil and gas activities. Despite industry claims of advanced treatment capabilities, compliance with regulations, and use of best practices, studies have shown increased levels of barium, strontium, and bromide since 2003 in streams in western PA with known brine effluents from centralized waste treatment ("CWT") plants (Vidic *et al.,* 2013). This result is a concern, in part, because of the potential for contributing to the formation of disinfection byproducts (DBPs) in drinking water. Disinfection byproducts are formed when disinfectants used in drinking water treatment react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Brominated forms of DBPs are considered to be more cytotoxic, genotoxic, and carcinogenic than chlorinated species (U.S. EPA, 2016a, p. 9-47). Laboratory studies have shown that HVHF wastewaters diluted by fresh water collected from the Ohio and Allegheny Rivers can generate and/or alter the formation and speciation of DBPs following various treatments, even at dilutions as low as 0.01 percent (Parker *et al.,* 2014). An investigation by the Pittsburgh Water and Sewerage Authority (the "Authority") of total trihalomethanes ("TTHMs"), a class of DBPs, in the Authority's finished water found that elevated bromide concentrations in the Allegheny River source water were associated with increased concentrations of TTHMs, and that industrial wastewater treatment plants treating Marcellus shale wastewater, as well as other wastewaters, were major contributors of bromide in the raw source water. Such discharges were substantially reduced in Pennsylvania in 2011. *See,* U.S. EPA, 2015f, p. 1; PADEP, 2011. The study results also indicated that the conventional treatment process used by the Authority for drinking water, which includes enhanced coagulation and secondary sedimentation, was ineffective in removing bromide from the source water (States *et al.,* 2013). A study of impacts of effluent from a treatment facility in western Pennsylvania that exclusively treated oil and gas wastewaters showed that a 500 to 3,000-fold dilution of the treated effluent would not reduce bromide levels to background, indicating that the wastewater discharge could potentially increase bromide concentrations at downstream drinking water intakes (Warner *et al.,* 2013a). A subsequent EPA study determined that the source of nearly all bromide at a public drinking water system intake on the Allegheny River in Western Pennsylvania was treated wastewater discharged from centralized waste treatment facilities for oil and gas wastewater (U.S. EPA, 2015f, p.2). A related, peer-reviewed journal article by the same team of EPA researchers showed that during low flow river conditions, the discharges increased bromide by 39 ppb (53 percent). This resulted in a modeled positive shift (41-47 percent) to more toxic brominated THMs (Landis *et al.,* 2016). Although these studies evaluated impacts of the discharge of treated oil and gas wastewater from conventional wells, the results provide an important indication of the potential impact of the discharge of treated HVHF wastewater on sources of drinking water. The EPA cited the research in its 2016 assessment of HVHF impacts to drinking water (U.S. EPA, 2016a, p. 8-56).

In 2018 the EPA completed a study that provides details on direct and measurable impacts on surface water quality and sediment and potential impacts on human health and aquatic life resulting from discharges by CWTs that treated oil and gas wastewater (including wastewater from both conventional and unconventional wells) (*see* U.S. EPA, 2018b). Among the conclusion of the study are the following:

> Levels of pollutants downstream from CWT facility discharges have been reported to exceed applicable thresholds, such as primary and secondary drinking water standards and acute and chronic water quality criteria for protection of aquatic life.
>
> . . . Drinking water treatment plants downstream of CWT facilities treating oil and gas extraction wastewater have noted a shift in the composition of DBPs [disinfection byproducts] from mostly chlorinated DBPs to mostly brominated DBPs, which are more toxic than their chlorinated analogues. These shifts could affect human health from consumption of treated waters.

(U.S. EPA, 2018b, p. 1-4).

A team of EPA researchers conducted a study to evaluate the probability of elevated bromide concentrations downstream from commercial wastewater treatment plants ("CWTPs") using data from CWTPs and river flow data in western Pennsylvania (Weaver *et al.,* 2016). The study constructed generic discharge and streamflow scenarios that illustrate the potential impacts from the discharge of five classes of effluent with different ranges of bromide concentrations. Under separate scenarios the release of each type of effluent from the CWTP locations was modeled using a mass and flow balance approach to determine the impact of various operations on the receiving water body. The historical flow records for the Allegheny River (median flow = 272 m^3/s, or 9,606 ft^3/s) and Blacklick Creek (median flow = 8.4 m^3/s, or 297 ft^3/s) were used to simulate both low-flow and high-flow conditions. Variations in all the parameters were examined using Monte Carlo methods, and results were evaluated to determine the probability that bromide concentrations would exceed critical thresholds of risk for downstream drinking water intakes. Results indicated that for effluents representing treated produced waters, the probability of exceedance in Blacklick Creek were 100 percent under both low- and high-flow conditions. The probability of exceedance in the Allegheny River was >75 percent under low-flow conditions and >5 percent under high-flow conditions. Probabilities decreased with downstream distance and at lower effluent concentration ranges.

Because of water quality concerns downstream of discharge points, PADEP in 2010 amended its wastewater treatment requirements under the Clean Streams Law for new discharges of TDS in wastewaters (*see* 25 Pa. Code §95.10), and in May of 2011, asked operators to stop delivering wastewater from shale extraction to wastewater treatment plants that were exempt from the 2010 TDS regulation. (PADEP, 2011). While to the best of DRBC's information, municipal wastewater treatment plants are complying with PADEP's request, no law or regulation fully prohibits all such discharges. Also, subsequent administrative settlements with EPA require the installation of controls that will reduce effluent concentrations from these plants (Weaver, *et al*., 2016). For these reasons, the probabilities described in the 2016 study by Weaver *et al.* reflect historical practices but do not represent current risks. The results of the study nonetheless further demonstrate that bromide in treated oil and gas effluent can impact drinking water supplies under a broad range of flow conditions.

A study by the U.S. Geological Survey also showed that discharges from oil and gas wastewater treatment plants are sources of DBPs (Hladik *et al.,* 2014). An EPA-led study was conducted to estimate bladder cancer risk from potential increased bromide levels in source waters of public drinking water systems in the United States that employ disinfection. Results based on data from 201 drinking water treatment plants indicate that a bromide increase of 50 μg/L could result in a potential increase of between 10^{-3} and 10^{-4} excess lifetime bladder cancer risk[37] in populations served by roughly 90 percent of these plants (Regli *et al.,* 2015).

Another study utilized a statistical simulation model to evaluate the effect of the increasing source-water bromide on THM formation and speciation and analyzed the changing risks (by using cancer slope factors) in treated water from 2010 to 2012. Even very low bromide concentrations were associated with increased cancer risk from THMs (Wang *et al.,* 2016).

Improving treatment for removal of bromide from HVHF wastewaters does not necessarily eliminate the risk of DBP formation. Research has shown that the introduction of debrominated production wastewater can lead to increased formation of some chlorinated DBP species in selected surface water and wastewater (Huang *et al.,* 2018).

Results of these studies on disinfection byproducts are highly relevant to the Delaware River Basin, as DBP formation is already a concern in public drinking water supplies for which the Delaware River is a source (PWD, 2007, p. 78). Bromide concentrations in CWTP effluents range from 0.60 to 8,290 mg/l (U.S. EPA, 2018b, p. 9-14), in comparison with those measured in six Upper Delaware River tributaries, which are less than 0.04 mg/l (DRBC, 2016). In the case of conventional wastewater treatment that may not effectively remove bromides, the discharge of HVHF wastewater to surface waters could potentially increase the formation of the more toxic species of DBP's – and thus the risk of adverse public health outcomes – in communities that rely for their drinking water on surface water downstream of a facility that is treating HVHF wastewater.

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[37] "Excess lifetime risk" is defined by the U.S. EPA as the additional or extra risk of developing cancer due to exposure to a toxic substance incurred over the lifetime of an individual. (EPA Integrated Risk Information System (IRIS) Glossary. https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=IRIS%20Glossary#formTop,

Many substances used in or resulting from hydraulic fracturing activity are known carcinogens, neurotoxins, endocrine disruptors, and/or are characterized by reproductive or developmental toxicity or adverse immune system effects. If these substances are not adequately removed through wastewater treatment, they may be present in downstream source water used for drinking water. A study by Yale University systematically evaluated 1021 chemicals in hydraulic-fracturing fluids or found in hydraulic fracturing wastewater for reproductive and developmental toxicity (Elliott *et al.,* 2017). Toxicity information was lacking for 781 (76 percent) of these chemicals. Of the remaining 240 substances, evidence suggested reproductive toxicity for 103 (43 percent), developmental toxicity for 95 (40 percent), and both for 41 (17 percent). The investigators found that a federal drinking water standard or guideline had been proposed for 67 of these substances. EPA has not promulgated MCLs for the other 954 substances, and therefore, no safe level in drinking water has been established for them. HVHF chemical toxicity and potential human health effects are discussed in Section 2.3.2.2, Pollution from Spills.

To help identify the type of chemical causing toxicity, researchers systematically separate a substance into fractions that vary according to differences in properties and then test the fractions individually. The organic fractions are sometimes targeted for this type of testing. An *in vitro* assessment of the endocrine disrupting potential of organic fractions extracted from hydraulic fracturing flowback and produced water was conducted by the University of Alberta. Results indicated that organic extracts of HVHF flowback and produced water can disrupt the binding activities of several nuclear receptors (i.e., the ability of the receptors to bind to DNA) at environmentally relevant concentrations, indicating the presence of substances that disturb the normal functioning of genes related to the endocrine system (He *et al.,* 2018b). According to the authors, the results "suggest that reclamation or remediation and risk assessment of [HF flowback and produced water] spills likely requires multiple strategies including understanding the properties of each spill with respect to fractured geological formation and physiochemical properties of the injected fluid." The impacts associated with releases of untreated HVHF wastewater (from spills and subsurface migration, for example) would likely be greater than the observed impacts from wastewater treatment plant discharges of oil and gas wastewater where that has occurred.

<u>Presence of HVHF chemicals in sources of drinking water:</u> Many studies have been conducted to investigate the presence of HVHF chemicals in surface water and groundwater in areas where HVHF-related activities are conducted. The source of the chemicals in some of these cases is unknown and could possibly include any of those described in Section 2.3.2, Significant Risks to Water Resources. The impact of HVHF activity on surface-water quality in the Appalachian region has been difficult to determine because baseline conditions are often unknown, or impacts have already resulted from coal mining and other human activities. The Susquehanna River Basin Commission examined trends in water quality in the Susquehanna River Basin and found an increasing trend in specific conductance at 24 stations (SRBC, 2017). However, watershed characteristics (including natural gas well density) for stations with increasing conductance trends were not statistically different from those of stations with no observable trend. In the section of the summary report entitled "NEXT STEPS," the report stated the following:

> To date, the Commission's remote water quality monitoring network has not detected discernible impacts on the quality of the Basin's water resources as a result of natural gas development, but continued vigilance is warranted. The Commission's next steps with the program include selecting a subset of

> stations with increasing conductance trends to further investigate the cause of increasing conductance.

The full SRBC Report states that their analysis resulted in *"inconclusive evidence for the presence of fractured wells influencing conductance trends."* (Hintz and Markowitz, 2016, p. 14 (emphasis added)). A subsequent SRBC report on water-quality monitoring in a smaller subset of stations was also inconclusive regarding impacts from HVHF activities (Berry, 2019).

The PADCNR Bureau of Forestry partnered with SRBC and others to conduct additional water quality monitoring of streams in Pennsylvania state forest lands where HVHF activities have occurred. More than 97 percent of all Pennsylvania state forest land within the core gas forest districts are within the Susquehanna River Basin. A report on these monitoring efforts concluded in part:

> Water quality monitoring efforts by the bureau and its partners have not raised significant concerns on state forest headwater streams to date. However, these are still relatively short-term results and may not be indicative of long-term or cumulative effects that can only be detected through long-term monitoring efforts.

(PADCNR, 2018).

A 2016 Study by the Northeast-Midwest Institute and the U.S. Geological Survey found that current basin-wide water quality monitoring is inadequate for determining if shale gas development activities systematically contaminate surface waters or groundwater in the Susquehanna River Basin (Betanzo *et al.,* 2016). More details about these and other SRBC studies are presented in Section 2.6.5 (Susquehanna River Basin Policies and Reports).

Although the basin-wide SRBC studies are inconclusive, a 2019 study by American University revealed evidence of HVHF impacts. The statistical analysis of water quality in small streams in southwestern Pennsylvania and western Maryland concluded that an index of oil and gas development had significant explanatory power for specific conductance, arsenic, strontium, and other cations. The study also found that other land use and land cover variables (forest, urban development, coal mining) as well as stream discharge and pH were also significantly associated with water quality composition. The results of this study suggest that water quality has been affected by oil and gas development in the Marcellus Shale region. The study design could not identify the causal mechanisms through which oil and gas development affects water quality constituents (Knee and Masker, 2019).

Evidence of endocrine disrupting chemicals in surface water and groundwater in the vicinity of HVHF activity has been observed in different geographic regions. Research has found evidence of endocrine disrupting chemicals in surface water and groundwater near HVHF-related activities in Pennsylvania and Colorado, in surface water in West Virginia and North Dakota, and in groundwater in Wyoming. The presence of endocrine disrupting chemicals in samples is determined by conducting laboratory assays that characterize various types of endocrine-related activities. Highlights of this research are noted below.

PENNSYLVANIA: Toxic and endocrine disrupting chemicals have been detected in surface water and groundwater near HVHF activity in Pennsylvania. A 2019 study of surface water and groundwater in Susquehanna County, PA, employed a new approach that found evidence of endocrine-disrupting chemicals near impaired gas wells. The approach characterized the biological consequence of pollutants in samples and the pollutants that may be responsible (Bamberger *et al.,* 2019). Samples were collected from 33 private wells, 6 streams, 9 ponds, 4 springs, and one lake. Sample proximity to various natural gas infrastructure, including gas wells, compressor stations, and gas dehydrators was determined. Natural gas wells in the county with known casing, cement sheath, and/or other impairments were also identified. The researchers assessed potential toxicity and endocrine activity of the samples with biological assays and determined chemical composition in bulk. The bulk chemical characterizations were then screened for association with anthropogenic activities. One of the biological assays conducted measures aryl hydrocarbon (Ah) receptor activity, which is an indicator of potential immunotoxicity. Other biological assays were conducted to assess endocrine disruption. Ah receptor activity exhibited a strong correlation with proximity to impaired natural gas wells. Endocrine receptor (ER) activities did not show such a correlation. It is not clear whether this lack of correlation is due to the absence of endocrine disrupting substances contributed by HVHF activity or simply the fact that other activities, such as agriculture, also contributed to the results. ER activity was found to be associated with potential hydraulic fracturing chemicals or wastewater constituents detected in some samples. The study detected 17 potential hydraulic fracturing additives or wastewater constituents that were associated with Ah activity, ER activity, and proximity to impaired wells. The study authors concluded that the association of these chemicals with biological activity and impaired wells suggests that anthropogenic activities, including hydraulic fracturing operations, have resulted in water contamination.

COLORADO: The majority of surface water and groundwater samples collected from sites in a region of dense oil and gas development in Colorado exhibited more estrogenic, anti-estrogenic, or anti-androgenic activities than reference sites with limited nearby oil and gas operations. These results suggest that nearby natural gas drilling operations may result in elevated concentrations of endocrine disrupting chemicals in surface and ground water (Kassotis *et al.,* 2014).

WEST VIRGINIA: Evidence of endocrine disrupting chemicals and endocrine disrupting activity above levels known to result in adverse health effects has been detected in surface water adjacent to and downstream from an oil and gas industry underground injection disposal site in West Virginia (Kassotis *et al.,* 2016).

NORTH DAKOTA: As part of a study led by the U.S. Geological Survey, geochemical and biological sampling downstream from a major HVHF wastewater pipeline leak in North Dakota found numerous persistent effects; bioassays of water samples showed estrogenic inhibition (one type of endocrine disruption), and fish bioassays showed reduced fish survival (Cozzarelli *et al.,* 2017).

WYOMING: Groundwater samples from HVHF gas-production areas and conventional oil production areas exhibited greater ER antagonist activities than water samples from conventional gas production areas. Samples from HVHF gas production areas tended to exhibit progesterone receptor antagonism more often, suggesting that there may represent a HVHF-related impact (Kassotis *et al.,* 2018).

Interviewed about this body of research on endocrine disruption, senior author Christopher Kassotis of Duke University summarized it this way:

> We have now reported similar endocrine bioactivities across numerous unconventional oil/gas sampling regions, and other researchers are beginning to demonstrate similar effects in cell and animal models. These, above all else, lend strong support for our findings.

(Thuermer, 2018). Although a lack of toxics information for specific chemicals is not unique to the hydraulic fracturing industry, the majority of chemicals associated with hydraulic fracturing have not undergone significant toxicological assessment (U.S. EPA, 2018b, p. 9-4). Some fracturing fluid ingredients are claimed to be confidential business information (CBI) that can remain undisclosed to regulators and the public. Therefore, the possible presence of unknown chemical constituents in wastewater contributes to uncertainty about the effectiveness and potential impacts of management strategies, particularly with regard to treatment efficacy. Moreover, unknown chemical constituents in inadequately treated wastewater discharges or accidental releases may be consequently present in downstream waters serving as raw water for treatment and use as drinking water. Without knowledge of such constituents or requirements for their removal, a downstream drinking water treatment plant operator cannot plan, operate, or test for the efficient removal of such constituents to acceptable levels and may unknowingly deliver such constituents in finished water, resulting in public exposure to toxic chemicals. The secrecy of chemical usage in HVHF activities is especially problematic for responding to accidental releases. The catastrophic fire in June 2014 at the Eisenbarth well pad in Clarington, Ohio serves to illustrate. The fire consumed the contents of the well pad and resulted in the release of fluids and a fish kill in a tributary to the Ohio River. Difficulties in responding to the incident were reportedly compounded by the unavailability of the CBI about proprietary chemicals present at the site. The EPA was not provided with this information for five days while the fire burned, and downstream water treatment plant operators had no knowledge of any proprietary chemicals that might have been present in the Ohio River source water as a result of the incident (Arenschield, 2014; Blake, 2014). The CBI issue has also reportedly hampered efforts to understand relations between hydraulic fracturing activities and health issues: Pennsylvania citizens attempting to link human illnesses and animal deaths to nearby HVHF drilling operations were reportedly unable to obtain a full list of chemicals involved, even with a court order requiring full disclosure by the company in charge of the drilling site (PFPI, 2018). These cases illustrate that the CBI issue, as it relates to HVHF activity, results in uncertainties that can 1) prevent regulators and emergency responders from performing their duties to protect the public including the safety of drinking water; and 2) prevent the impacted public from pursuing redress. Additional details regarding the CBI issue are presented in Section 2.6.2 Chemical Disclosure.

<u>Impacts to drinking water resources from road spreading of HVHF wastewater:</u> Wastewater reuse for roadway spreading (for de-icing or dust control) also presents a potential risk to drinking water resources. From July 2009 to June 2010, about 13,000 gallons of Marcellus Shale hydraulic fracturing wastewater was reportedly spread on roads in Pennsylvania (Rozell and Reaven, 2011). Although there is no permanent regulation regarding road spreading, the spreading of unconventional produced water on Pennsylvania roadways is presently prohibited, and this practice is not currently in use in Pennsylvania (PADEP, 2019a; See, 25 Pa.Code §§ 78a.70 and 78a.70a). Concerns about road application center on contaminants such as barium, strontium, and radium. A 2018 study led by Penn State University found that oil and gas wastewaters spread on roads in the northeastern U.S. have salt, radioactivity, and organic contaminant concentrations often many times above drinking water standards (Tasker *et al.,* 2018). The study also found that in Pennsylvania from 2008 to 2014,

spreading oil and gas wastewater on roads released over 4 times more radium to the environment (320 millicuries) than oil and gas wastewater treatment discharges and 200 times more radium than spill events. Lab experiments conducted as part of the study demonstrated that nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water. Currently, state-by-state regulations do not require radium analyses prior to treating roads with oil and gas wastewaters.

Brine spreading on roadways is not addressed by the proposed or final rulemaking. Additional detail about roadway spreading is presented in Section 2.7.7, Application of Hydraulic Fracturing Produced Water/Wastewater.

Examples of Documented Impacts to Drinking Water Resources

The Commission disagrees with the assertion that hydraulic fracturing has not polluted water supplies. Regulatory documents and the literature are replete with examples of pollution of water supplies from HVHF and related activities, including well-documented cases such as those in Bainbridge, OH (22 private domestic wells and one public water supply well; ODNR, 2008, p. 6); Dimock, PA (18 private domestic wells; PADEP, 2009; PADEP, 2010); other areas in Susquehanna and Bradford Counties, PA (9 private domestic wells; U.S. EPA, 2015d, p.109); and many other locations in PA (PADEP, 2019d), including cases that resulted in a PADEP-issued Consent Assessment of Civil Penalty or Consent Order and Agreement in response to impacted wells such as those cases in Bradford and Sullivan Counties (PADEP, 2018c), Nicholson Township, Wyoming County (PADEP, 2017a), Forks Township and Elkland Township, Sullivan County (PADEP, 2016a), and Donegal Township, Westmoreland County (PADEP, 2016a), and elsewhere, as documented by the EPA (U.S. EPA, 2016a, pp. ES 30-41, 6-23 - 6-25) and in other cases noted previously. The attribution of the impact to a specific stage of the HVHF process can be difficult. In the case of the Bainbridge, OH incident, the cause of the pollution is known to be the hydraulic stimulation of an improperly cemented well. In other cases, a determination was made that the pollution was the result of HVHF activity, but the specific HVHF activity is uncertain.

DRBC disagrees with the assertion by a commenter that the 2017 TAMEST report (TAMEST, 2017) supports a conclusion that hydraulic fracturing is not a significant threat to drinking water supplies. In addition to the quote offered by the commenter, the TAMEST report also reached these additional conclusions indicating that hydraulic fracturing can pose a risk to water supplies:

> . . . there is, and always will be, some probability of casing failure leading to near surface contamination or contributing to surface spills due to flow up the failed casing.

(TAMEST, 2017, p. 123).

> Hydraulic fracturing is also a potential concern to drinking water supplies. There is little chance of migration of hydrocarbons or brines from producing formations to drinking water aquifers, but near surface and surface spills or leaks may pose the dominant risk of hydraulic fracturing operations to water resources. Increased complexity of surface fluid management, for example by

> treatment and use/reuse operations, may increase the potential for spills or leaks and therefore the risk to land and water resources.

(*Id.*, p. 127).

Also, the quote presented by a commenter from page 128 of the TAMEST report may not be applicable to the geologic setting of northeastern PA. The geologic structure and glacial history of the region may result in conditions that are more conducive to subsurface contaminant migration from target formations and shallower gas-bearing formations to freshwater aquifers. Details of this geologically-based vulnerability of the Delaware River Basin are explained in Section 2.3.2.3 in responses to comments on Pollution from Fluid Migration.

DRBC agrees with and relies on the conclusions of current science and risk assessment procedures that hydraulic fracturing can impact drinking water resources and that the resource vulnerabilities and impacts related to hydraulic fracturing identified in the 2016 EPA report (and in other studies, including the TAMEST study) can vary in frequency and severity depending upon multiple factors that are both within and beyond human control.

Examples of incidents in which drinking water resources were impacted by unconventional gas development illustrate the potential consequences of these risks and are presented below.

<u>Noted impacts to drinking water in Pennsylvania, Wyoming, and Texas:</u> The three cases of impacts to drinking water resources in Pennsylvania, Wyoming, and Texas cited by the commenter have relevance, although there is uncertainty about specific migration pathways and sources of contaminants. The PADEP investigated impacts caused by HVHF-related activities in Dimock, PA and made a determination that 18 water wells tapping groundwater in the Catskill Formation and located within a 9 square mile area had been negatively affected by natural gas extraction activities. This case resulted in at least three signed Consent Order and Agreements (COAs) between the PADEP and Cabot Oil and Gas Corporation (with civil penalties totaling at least $860,000; PADEP, 2009; PADEP, 2010). The case also resulted in a Health Consultation report by the U.S. Agency for Toxic Substances and Disease Registry (ASTDR). This report concluded that methane levels measured in five residences were over 28 mg/l and posed an immediate risk of explosion or fire and that levels measured in 12 additional residences exceeded a cautionary level of 10 mg/l. The report also concluded that chemicals in 27 private wells at the site were detected at concentrations high enough to affect health (U.S. HHS, 2016). Studies conducted in the area have disagreed on the source of the methane found in the drinking water in homes in Dimock. Although the specific role of hydraulic fracturing in the migration of gas to the Catskill Formation and the specific pathways by which this migration from HVHF activity occurred are uncertain, PADEP concluded that HVHF-related activities were a cause of the migration of methane into the private wells (DEP, 2009; PADEP, 2010). The Dimock case preceded updates to Pennsylvania's well construction and operation regulations in 2011 (*see* Appendix-4). A significant portion of those regulations were adopted in response to the Dimock case.

In the area around the Pavilion gas field in Wyoming, a study by Stanford University found that organic contaminants in domestic wells resulted from subsurface migration of these contaminants from unlined pits used to dispose diesel-fuel based drilling mud and production fluids (DiGiulio and Jackson, 2016).

The Commission notes that Pennsylvania on October 8, 2016 promulgated new regulations to address surface impacts resulting from unconventional well development. See, 25 Pa. Code Ch. 78a ("Unconventional Wells"). Under Chapter 78a, the use of pits is prohibited for "temporary storage" of "regulated substances used at or generated at a well site[,]" including, "all regulated substances which are used or produced during drilling, altering, completing, recompleting, servicing and plugging" an unconventional well. 25 Pa. Code §§ 78a.56(d) (pits prohibited), 78a.56(a) (regulated substances…), and 78.56(a)(1) (used or produced …). Storage of brine and other fluids produced by a well—whether "temporary" or on a longer term basis—must be stored in "a tank or series of tanks, or other device approved by the Department …." Id., §§ 78a.56(a) and 78a.57(a) (same language). As to temporary storage of regulated substances and wastes, any pits in use as of October 18, 2016 were to be "properly close[d] … in accordance with appropriate restoration standards no later than April 8, 2017." An operator using a pit for storage of production fluids was required to "report the use of the pit to PADEP no later than April 8, 2017, and … properly close the pit in accordance with appropriate restoration standards no later than October 10, 2017." Id., § 78a.57(a).

Pennsylvania unconventional well operators must comply with the storage requirements of Chapter 78a or obtain applicable permits (available for all industries) under the Solid Waste Management Act (35 P.S. §§ 6018.101-6018.1003) or the Clean Streams Law (35 P.S. 691.1 – 691.1001).

Chapter 78a also required any operator using a centralized impoundment as of October 8, 2016 to submit a closure plan for such facility by April 8, 2017 and either close the facility or obtain a permit in accordance with the Department's residual waste regulations, 25 Pa. Code Subpart D, Article IX, by October 8, 2019. *See,* 25 Pa. Code § 78a.59c(a). In response to a challenge by the Marcellus Shale Coalition, these regulatory compliance deadlines were tolled by a preliminary injunction of the Pennsylvania Commonwealth Court. By court order dated January 6, 2021, operators of existing centralized impoundments must submit a closure plan to the PADEP for review and approval by June 7, 2021, and centralized impoundments must be closed in accordance with the approved plan or re-permitted in accordance with the applicable residual waste management regulations by January 8, 2024. See, 51 Pa.B. 639 (Jan. 30, 2021).

Because of disagreement in the findings of the peer-reviewed studies conducted within the Barnett Shale area, which includes Parker County, Texas, the cause of gas leakage in the Parker County, Texas case cited by the commenter is uncertain. One study examining hydrocarbons and dissolved noble gases in drinking-water wells suggested that a likely pathway for gas leakage to the Trinity Aquifer is the failure of the gas well annulus cement, allowing natural gas to migrate from formations located between the Barnett Shale and the Trinity Formation to overlying intervals including the Trinity aquifer (Darrah *et al.,* 2014). Other studies that used noble gases and other methods suggested that the source of the stray gas was local gas accumulations known to be present in the shallow subsurface, and not the result of hydraulic fracturing activity (Larson *et al.,* 2018; Nicot *et al.,* 2017; Wen *et al.,* 2016).

Many other examples and evidence of impacts to drinking water resources from unconventional gas development are documented. Some of these examples and some of this evidence are presented in the EPA 2016 assessment report, and in responses to more specific comments below.

<u>Impacts to drinking water resources as a result of HVHF-related spills:</u> HVHF drilling operations entail the transport and storage of tens of thousands of gallons of chemicals and fuels in tanks and

trucks, often to and on remote sites on unpaved roads, injection of millions of gallons of hydraulic fracturing fluids into the ground at high pressure, and storage of flowback and produced water on-site. Produced waters stored on-site may be recycled for hydraulic fracturing and transported through pipelines for reuse or treatment. These fluids and fluid flows constitute a large mass of potential contaminants that pose a threat to drinking water from uncontrolled spills or releases. Examples of sudden, uncontrolled releases of thousands of gallons of fluids and/or produced waters include documented incidents in Bradford County, Pennsylvania in 2011 (Gilliland, 2011; Considine *et al.,* 2012) (gas well blowout); Clarington, Ohio in 2014 (U.S. EPA, 2014) (Eisenbarth well pad fire); Williston, North Dakota in 2015 (News@prairiebizmag.com, 2015; Cozzarelli *et al.,* 2017) (produced water pipeline rupture); and Powhatan Point, Ohio in 2018 (Grego, 2019; U.S. EPA, 2018a) (well pad explosion and fire). Details of these incidents are provided in Section 2.3.2.2, Pollution from Spills, in response to comments relating to spills. EPA estimates that of the gas wells hydraulically fractured in 25 states between 2000 and 2013, 8 percent were located within 1 mile of at least one groundwater well or surface water intake providing public water supply. Most of these public water supplies were located in nine states, including Pennsylvania (U.S. EPA, 2016a, p. 2-14). With increased proximity, hydraulic fracturing activities have a greater potential to affect surface and subsurface sources of current and future drinking water (U.S. EPA, 2016a, p. 2-1).

Two incidents in Pennsylvania illustrate the disruption and loss of public confidence that can occur when gas or fluids are accidentally released from unconventional gas wells near public water supplies, even if the public water supplies do not become contaminated. In September 2015, an incident occurred at an unconventional gas well being drilled in Potter County, Pennsylvania. During drilling operations by JKLM Energy, LLC, a chemical surfactant (isopropanol) was injected into an uncased borehole, and several nearby residents reported foaming drinking water from their private wells (Troutman, 2015). According to a Health Consultation report by ASTDR, isopropanol was subsequently detected in three private wells, and levels in one of the impacted wells was high enough to be a health concern (U.S. HHS, 2018). The local water authority and a nearby hospital reportedly suspended the use of specific public water supplies as a precaution and switched to alternative sources. Water buffalos were made available to affected residents. An emergency meeting was held in Coudersport, PA to inform the public. This incident was reportedly the first time that public water supplies (as opposed to only private drinking water wells) were impacted to the point of being shut down due to the potential for groundwater contamination from unconventional oil and gas operations (Troutman, 2015). JKLM Energy LLC was fined $472,317 for the discharge of the surfactant (Hess, 2016).

In January 2019, an incident occurred at an unconventional Utica Shale gas well in Westmoreland County, Pennsylvania that was being hydraulically fractured (Litvak, 2019). The horizontal stretch of the well (or lateral) extends under the Beaver Run Reservoir, the source of public water supply serving a local population of 150,000. During hydraulic fracturing process, an apparent casing rupture occurred in the vertical stretch (or tophole) of the well, resulting in a dramatic loss of pressure in the well, inter-wellbore communication with several shallower surrounding conventional gas wells, and a spike in pressure in the surrounding gas wells. Sampling of the reservoir and surrounding private wells did not indicate that contaminants had impacted any water supplies. Local environmental advocacy groups called for an end to all well drilling and hydraulic fracturing near the reservoir and increased testing. The incident remained under investigation as of February 28, 2019 (Himler, 2019). Despite issuance of a notice of violations against the operator and heightened public awareness of the incident and the vulnerability of the reservoir, the legal contracts between the Municipal Authority responsible for the reservoir and the energy companies prevented the Authority from halting the drilling activity (Cholodofsky, 2019).

The Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, and adverse impacts to drinking water would inevitably occur, as the result of spills, releases and discharges of harmful pollutants, including gas, salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined.

Statement of Concern (SC-50)

Several commenters with individual private wells serving their homes express concerns over the documented adverse impacts to local groundwater sources. They state there is evidence that homeowner wells become unusable following and attributable to natural gas hydraulic fracturing activities.

Response (R-50)

The EPA and the NYSDEC have both concluded that hydraulic fracturing activities have in the past and can in the future adversely impact drinking water resources in different settings and circumstances (U.S. EPA, 2016a; NYSDEC, 2015a). Over the many decades of oil and gas development in Pennsylvania, failures of well integrity have contributed to hundreds of documented cases of water supply impacts and, in some cases, gas explosions resulting in injuries and fatalities (PADEP, 2018a). In a particularly severe case in Dimock, PA, the Pennsylvania Department of Environmental Protection (PADEP) investigated and made a determination that 18 domestic water wells located within a 9 square mile area were negatively affected as a result of natural gas extraction activities (PADEP, 2009; PADEP, 2010). In another case, the PADEP determined that a faulty cement job on a gas well in Lycoming County resulted in gas migration into private drinking water wells and a stream. The leakage has continued since 2011, resulting in a DEP-issued order directing the drilling company to fix the leak. The drilling company continued to deny responsibility (Levy, 2020). As of September 22, 2020, the PADEP had identified and published letters documenting 356 cases in which a private water supply was impacted by oil and gas activities. This compilation included impacts linked to both conventional and unconventional drilling activities (PADEP, 2019d). Additional details regarding these cases are presented below in this response to comment SC-50.

A study of organic compounds in private wells in northeastern Pennsylvania found trace levels of known constituents of hydraulic fracturing fluid in wells in close proximity to active shale gas wells and disclosed Environmental Health & Safety violations. The study concluded that the presence of the compounds was consistent with surface spills of disclosed HVHF chemical additives (Drollette *et al.,* 2019).

A study of Pennsylvania domestic wells impacted by stray gas and a known HVHF additive utilized multiple line of evidence to test different hypotheses about the source of the contamination. The study concluded that stray gas and drilling or hydraulic fracturing fluids may have flowed vertically along improperly constructed well boreholes and then approximately 1-3 kilometers (0.62 – 1.9 miles) along shallow and intermediate depth fractures to the aquifer supplying water to the impacted domestic water supply wells. Wastewater from a reported pit leak at the nearest gas well pad may have been a source of the hydraulic fracturing fluids (Llewellyn *et al.,* 2015). Additional details about this study are presented in Section 2.3.2.3 (Pollution from Fluid Migration).

Not only have scientists and the PADEP found contamination of surface and ground water sources as a result of HVHF-related activities in PA, but so have Pennsylvania tribunals. In his 2016 opinion in *Kiskadden v. Pa. Dept. of Envtl. Prot.*, Judge Wojcik found that the appellant, an Amwell Township, Washington County resident, did not meet his burden of proving that the natural oil and gas drilling wastewater impoundment on a nearby property known as the "Yeager Site" had contaminated his well water. The judge nevertheless opined, "[T]here is little dispute that the activities at the Yeager Site impacted the environment and contaminated the soil and adjacent springs . . . ." *Kiskadden v. Pa. Dept. of Envtl. Prot.*, 149 A.3d 380, 21 (Pa. Cmmw. Ct. 2016). In *EQT Production Co. v. PADEP,* 193 A.3d 1137 (Pa. Commw. Ct. 2018), the Commonwealth Court affirmed the EHB's assessment of civil penalties for violations of the Clean Streams Law resulting from a release of wastewater through a damaged impoundment liner. The court found that EHB's determination that contaminated water infiltrated the groundwater "is supported by substantial evidence of record." *Id.* at 1160.

Following a multi-year grand jury investigation of HVHF impacts, the Pennsylvania Attorney General charged Range Resources with negligent oversight of its activities on the Yaeger site, to which Range pleaded no contest (Phillis, 2020).[38] The grand jury investigation included testimony of more than 70 households that claim to have suffered harm from HVHF operations on or near their property. In addition to descriptions of adverse health effects such as burning rashes from exposure to contaminated water, the testimony detailed the contamination, and in some instances complete loss, of homeowners' water supply (PA OAG, 2020, pp. 27-47.)

A community-based study of 66 residences in and near Belmont County in eastern Ohio explored HVHF well proximity in relation to water contamination and health symptoms. The study found that contaminant detection and concentrations decreased with greater distance to HVHF gas wells. The study also found that HVHF well proximity was associated with increased incidence of adverse general health symptoms such as fatigue (Elliott *et al.,* 2018).

Additional information regarding the potential for HVHF to adversely affect domestic water supply wells is provided in the responses to Statements of Concern Numbers SC-51 and SC-52, below.

Statement of Concern (SC-51)

Many commenters asserted that the PADEP has received thousands of complaints about environmental problems in shale gas areas and has acknowledged more than 300 cases of private water well contamination caused by oil and gas operations in the Commonwealth. Commenters have suggested

[38] Pennsylvania regulations finalized in 2016 require a residual waste storage permit for the operation of centralized impoundments such as that operated by Range Resources on the Yaeger site for the storage of unconventional well (HVHF) wastewater. *See* 25 Pa. Code § 78a.59c.

that the number of acknowledged cases of impacts and contamination underrepresents the actual number of cases for several reasons (paraphrased):

- The number does not include ongoing investigations or cases that were settled and are now subject to non-disclosure agreements.
- There are cases for which, in the view of PADEP analysts, the available evidence was insufficient to support a determination that oil and gas operations were the cause of the impacts, and in which the cause(s) remain unresolved.
- PA regulations define a limited zone of influence around a gas well and a limited time period that can be considered in determining whether a water supply has been impacted by oil or gas operations.
- PADEP does not deem methane migration into water wells caused directly or indirectly by hydraulic fracturing to be a pollution incident, and yet such migration can render a water well unusable and has health and safety impacts for the residents.

Response (R-51)

The available data and information on complaints to PADEP about HVHF operations (Troutman and Pribanic, 2017; Pribanic and Troutman, 2015) make clear that many thousands of complaints, including many related to water supply, have been submitted. Important details about the incidents that gave rise to the complaints are not always included in the available records. In response to some but not all complaints, the PADEP conducted an investigation. Hydrogeologic investigations are complex, and PADEP must make water supply impact determinations based on sufficient evidence. When PADEP has taken action against a well operator in response to an incident involving water supply impacts, available records are more detailed. As of September 22, 2020, PADEP had identified 356 cases that resulted in the issuance of a Water Supply Determination letter stating that a water supply was impacted by oil and gas activities (conventional or unconventional), and that the well operator was required to remediate the situation (PADEP, 2019d). Impacts that have resulted in a Water Supply Determination letter include water diminution (reduced yield) or an increase in constituents above background conditions. Contrary to the commenter's assertion, PADEP *does* consider methane contamination to be a pollution incident, and methane contamination is frequently listed as an impact (Brantley *et al.,* 2014). Many of the water supply impacts reported to PADEP have since abated, with constituent concentrations returning to background; many have been mitigated through the installation of water treatment; and others have been addressed through the replacement of the original water supply.

The legal significance of a Water Supply Determination letter is established by Section 3218 of the 2012 PA Oil and Gas Act, which provides that:

> [a]ny well operator who affects a public or private water supply by pollution or diminution shall restore or replace the affected supply with an alternate

source of water adequate in quantity or quality for the purposes served by the supply.

Contrary to the commenter's statement about a limited zone of influence, there are no timing or proximity limitations to this obligation. However, the regulations do include a presumption of liability rule, whereby a natural gas well operator is presumed to have caused pollution or diminution (reduced yield) of a water supply located within 2,500 feet of an unconventional well and within 12 months of completion, drilling, stimulation or alteration of the well (or within 1,000 feet of a conventional well and within 6 months of drilling or well completion). This means the well operator is deemed to be responsible and legally liable, regardless of the actual cause, unless the operator can prove otherwise.

Because the cause of ground water quality impairments is difficult to determine, and some impacts may be undocumented, the number of determination letters issued by PADEP is an indication, but not dispositive evidence, of the number of incidents caused by well operations. The Commission cannot speculate on the content of non-disclosure agreements or the number of contamination incidents that may remain undocumented for this reason. However, an extensive database of HVHF litigation nationwide documents many additional cases of alleged impacts to water resources. *See,* Watson, 2020; *also see*, Watson, 2017.

On August 8, 2020, the PADEP published its "Policy for the Replacement or Restoration of Private Water Supplies Impacted by Unconventional Oil and Gas Operations" (PADEP, 2020b). The need for the adoption of this 19-page policy is indicative not only of the complexity of certain requirements in the 2012 Oil and Gas Act, The Clean Streams Law, and 25 Pa. Code Chapter 78a; but also of the severity and regularity of adverse impacts to private water supplies by HVHF activities in Pennsylvania.

Many of the water supplies determined by PADEP to have been impacted by oil and gas well operations were the subjects of more detailed investigations of HVHF impacts. *See, e.g.,* Wen *et al.,* 2018; Li *et al.,* 2016b; Llewellyn *et al.,* 2015; Siegel *et al.,* 2015a; U.S. EPA, 2015d; Brantley *et al.,* 2014; Darrah *et al.,* 2014; Jackson *et al.,* 2013b; Osborn *et al.,* 2011. Additional information regarding HVHF impacts to private wells and discussion of these studies is provided in response to SC-52 below.

Statement of Concern (SC-52)

A study suggests that some homeowners living <1 km (<0.62 mi) from gas wells have drinking water contaminated with stray gases, including methane, ethane, and propane.

Response (R-52)

The likelihood that HVHF will adversely impact water quality and drinking water supplies due to the migration of gas and/or fluids is a complex question and the subject of many investigations and research activities. A 2015 EPA report concluded that while proximity alone does not determine impacts, it is a factor that should be considered when assessing the potential for hydraulic fracturing to affect drinking water resources (U.S. EPA, 2015h, p. 56). Many scientific papers and reports document occurrences and evidence of gas and/or suspected hydraulic fracturing fluids or produced water in groundwater in different settings and circumstances. Comprehensive and authoritative reports that synthesize much of this information are the 2016 EPA final assessment report (U.S. EPA, 2016a) and the NYSDEC Final Supplemental Generic Environmental Impact Statement (SGEIS) (NYSDEC, 2015a). These reports conclude that hydraulic fracturing activities can adversely impact and have adversely impacted drinking water resources. DRBC agrees with and relied upon the science-based data, methods, and conclusions set forth in the EPA final assessment report, the New York State Department of Environmental Conservation SGEIS, and other peer-reviewed analyses to inform its rulemaking. Examples of scientific research exploring the potential effects of HVHF on private wells and the relation between stray gas in private wells and proximity to gas wells are presented below.

The presence of naturally occurring methane in groundwater in much of northeastern Pennsylvania complicates the process of determining whether methane in a particular water supply well is naturally occurring or the result of a human activity such as HVHF. Methane is present in formations overlying the Marcellus Shale (Baldassare *et al.,* 2014), and there is historical documentation of methane in shallow groundwater in the Marcellus region dating to the late 1700s. Testing of over 1701 water-supply wells as part of a pre-drill water well survey showed that methane is commonly found in shallow groundwater in northeastern Pennsylvania (Molofsky *et al.,* 2013). Water testing parameters, including noble gases, isotopes, higher-chain hydrocarbons, and evaluation of other water-quality parameters in addition to methane are typically required in order to learn more about methane sources and mechanisms of gas migration.

Several studies have investigated the relation between the incidence of elevated methane in water wells and proximity to gas wells. The findings of this type of research are sometimes controversial. One study examined methane concentrations in water sampled from 68 private wells in parts of northeastern Pennsylvania and upstate New York (Osborn *et al.,* 2011). The wells draw from aquifers that overlie deeper formations including the Marcellus Shale and Utica formations. Results showed that average and maximum methane concentrations increased with proximity to gas production wells, and that average methane concentrations were 17 times higher in samples from wells located less than 1 km from gas production wells than in samples from wells located farther from gas production wells. The average methane concentration for samples from wells less than 1 km from gas production wells (19.1 mg/L) fell within the defined action level (10–28 mg/L) for hazard mitigation recommended by the U.S. Department of the Interior. Results of isotope analyses and ratios of methane-to-higher-chain hydrocarbons (ethane and propane), suggest that the elevated methane concentration is from thermogenic sources such as the Marcellus Shale and Utica Shale. The composition of the gas matched the gas geochemistry of gas from production wells nearby. The study did not, however, identify any specific mechanisms of gas migration.

A more expansive follow-up study included a larger dataset in Pennsylvania and, in addition to methane, included ethane and propane, two hydrocarbons that are associated with thermogenic sources and are not derived from biogenic activity (Jackson *et al.,* 2013b). Average methane and ethane concentrations were many times higher for homes <1km from gas wells. Propane was detected in 10 wells within about 1 km from gas wells. The data suggest that some wells located <1 km from gas wells are contaminated with "stray" gas.

A subsequent study investigated sources and mechanisms of methane contamination in several clusters of wells drawing water from aquifers overlying the Marcellus Shale in Pennsylvania and the Barnett Shale in Texas (Darrah *et al.,* 2014). Methane concentrations increased over a short period of time (nine months), indicating that the gas migration was occurring rapidly and not gradually through geologic time. Analyses of isotopic compositions and hydrocarbon abundance indicated thermogenic sources, and linked contamination to gas leakage from intermediate-depth strata through failures of gas well annulus cement (four clusters); faulty production casings (three clusters); and underground gas well failure (one cluster). Subsequent studies in the Barnett Shale region using noble gases and other methods did not indicate that gas-well integrity was a factor in the gas migration (Larson *et al.,* 2018; Nicot *et al.,* 2017; Wen *et al.,* 2016). A retrospective study conducted by the U.S. EPA (U.S. EPA, 2015d) examined samples from 36 wells in northeastern Pennsylvania located within 1 mile of gas wells and found that the source of gas present in nine of the wells was thermogenic and likely not the result of a natural background condition. Another study of stray gas occurrence in Bradford County, PA used data mining techniques to map a few hotspots where methane in groundwater significantly correlates with distance to faults and gas wells (Li *et al.,* 2016b). Results of these studies provide strong evidence that some gas production wells are adversely impacting nearby private wells in parts of northeastern Pennsylvania and elsewhere. Some other studies, including a study of Utica Shale region in Ohio and an industry-funded study of Marcellus Shale region in northeastern Pennsylvania, explored the relation between elevated methane concentrations in private wells and proximity to gas wells and reached a contrary conclusion (Botner *et al.,* 2018; Siegel *et al.,* 2015a).

The weight of evidence from these and other studies and data indicates that HVHF activities have adversely impacted private wells in Pennsylvania, and that proximity to gas wells is an important factor in the likelihood of such impacts. This is part of the justification for a provision of Section 3218 of the PA Oil and Gas Act that presumes liability on the part of a natural gas well operator wherever pollution or diminution of a water supply occurs within 2,500 feet of an unconventional well and within 12 months of completion, drilling, stimulation or alteration of the well (or within 1,000 feet of a conventional well and within 6 months of drilling or completion of the well).

Additional information regarding the potential for HVHF impacts to water resources from fluid migration through natural or stimulated fractures or as a result of gas well integrity failure is available in Section 2.3.2.3 (Pollution from Fluid Migration) of this Comment Response Document.

Statement of Concern (SC-53)

Review of available approved dockets from the DRBC website indicates that public water supply intakes on the Delaware River are rare in SPW s and most are more than 100 hundred river miles downstream of Wayne and Pike Counties, the area of likely natural gas development and associated produced water treatment. The concern over potential discharge impacts affecting down-stream public drinking water supply withdrawals is nonexistent.

Response (R-53)

There are over 850 groundwater and surface water withdrawals for public water supply in the SPW area of the Delaware River Basin, of which, about 320 are in areas underlain by the Marcellus Shale. Moreover, nearly 150 of these withdrawals are located in Pike and Wayne Counties. Unconventional gas wells in proximity to public water supplies are not uncommon: EPA estimates that of the gas wells hydraulically fractured in 25 states between 2000 and 2013, 8 percent were located within 1 mile of at least one groundwater well or surface water intake providing public water supply. Most of these wells and intakes were located in nine states, including Pennsylvania. With increased proximity, hydraulic fracturing activities have a greater potential to affect surface and subsurface sources of current and future drinking water (U.S. EPA 2016a, p. 2-1).

Additional information regarding the HVHF risks to drinking water from chemical spills, fluid migration, and wastewater handling and disposal are presented in Sections 2.3.2.2, Section 2.3.2.3 and Section 2.3.2.4, respectively.

DRBC agrees with the conclusions of the 2016 EPA study that hydraulic fracturing can impact drinking water resources and that the resource vulnerabilities and impacts related to hydraulic fracturing identified in the report can vary in frequency and severity depending upon multiple factors that are both within and beyond human control.

Statement of Concern (SC-54)

Many commenters expressed concern about potential impacts to NYC drinking water:

NYC has some of the best drinking water in the nation because it has a protected watershed upstate. NYC's source water does not need to be filtered or treated extensively. However, if the Delaware River Basin's water becomes contaminated, the citizens of NYC would be exposed to the unfiltered polluted water requiring the construction or upgrade of extensive water treatment facilities at great cost (billions of dollars), time, and inconvenience to New York City and New York State, and ultimately to residents.

Response (R-54)

The State of New York conducted an exhaustive evaluation of the potential for significant adverse environmental and public health impact of high volume hydraulic fracturing activity and reported the results of this evaluation in a Final Supplemental Generic Environmental Impact Statement (SGEIS) and associated Findings Statement (NYSDEC, 2015a; NYSDEC, 2015b). The SGEIS concluded that HVHF activity is not consistent with the preservation of the NYC watershed as an unfiltered drinking water supply, and that this activity could result in a degradation of drinking water supplies from accidents, surface spills, etc. The SGEIS further concluded that such large-scale industrial activity, even without spills, could imperil EPA's Filter Avoidance Determinations and result in the affected municipalities incurring substantial costs to filter their drinking water supply. The Commission acknowledges the importance of protecting source waters and the continuing success in protecting NYC water sources in the Delaware River Basin. The final regulations protect water quantity and quality as well as aquatic life and other water-dependent natural resources by prohibiting high volume hydraulic fracturing within the Delaware River Basin (*see,* 18 C.F.R. § 440.3(a)).

Statement of Concern (SC-55)

Commenter states that the DRB includes a portion of the New Jersey Coastal Plain aquifer, which is an EPA-designated Sole Source Aquifer which provides water for millions of people, including Philadelphia. Hydraulic fracturing-related contamination could threaten the viability of this drinking water source and leave few alternatives.

Response (R-55)

The U.S. Geological Survey has shown that the Delaware River is a source of recharge to the New Jersey Coastal Plain (NJCP) aquifer (Navoy and Carleton, 1995), and so a hydrologic linkage does exist between potential discharges of HVHF wastewater or releases of HVHF fluids and the NJCP aquifer. The New Jersey Coastal Plain aquifer provides water for millions of people living in southern New Jersey, but it is not a source of water supply for Philadelphia (Zapecza *et al.,* 1987). The specific threat posed by HVHF to the NJCP aquifer has not been investigated. As noted in Section 1.5, the risks related to the importation of treated HVHF wastewater may be addressed by a separate rulemaking.

The regulations address ground water quantity and quality concerns by prohibiting high volume hydraulic fracturing within the Delaware River Basin (*see* proposed 18 C.F.R. § 440.3(a)). DRBC agrees with the conclusions of the 2016 EPA final assessment report that hydraulic fracturing can impact drinking water resources and that the resource vulnerabilities and impacts related to hydraulic fracturing identified in the report can vary in frequency and severity depending upon multiple factors that are both within and beyond human control. DRBC relied upon the science-based data, methods, and conclusions set forth in the EPA report, the New York State Department of Environmental Conservation SGEIS, and other analyses to inform its rulemaking.

Statement of Concern (SC-56)

The Delaware River is the back-up drinking water source for South Jersey. If we take fresh water away from the Delaware River for hydraulic fracturing activities, we are directly threatening this supply for most of South Jersey. Taking a fresh water source, using it once, and then downgrading the quality of that water so it's no longer potable for drinking water is unacceptable.

Response (R-56)

The Delaware River is a primary source of water supply for southern New Jersey, especially in the counties of Burlington, Camden and Gloucester (NJDEP, 2014). The proposed regulations address ground water quantity and quality concerns by prohibiting high volume hydraulic fracturing within the Delaware River Basin (*see* proposed 18 C.F.R. § 440.3(a)).

Statement of Concern (SC-57)

Hydraulic fracturing in our 9 square miles along Cooks Creek, an Exceptional Value stream, would jeopardize our drinking wells.

RESPONSE (R-57)

The Cooks Creek Watershed in Bucks County, PA is more than 15 miles south of the southeastern limits of the Marcellus and Utica shale formations, respectively. Thus, no potential for gas development using HVHF from these formations in the drainage area of Cooks Creek exists. Part of the Cooks Creek Watershed is within the mapped extent of the South Newark basin, another geologic formation that may contain oil and gas deposits capable of extraction using HVHF (*see* Figure 1 of this document). However, in 2012 the Pennsylvania legislature enacted a moratorium on drilling in the South Newark basin, to expire on January 1, 2018 (*see* 2011 Pa. Laws 1263, sec. 1607-E (adopted June 29, 2012)). The legislature subsequently repealed the expiration date, effectively extending the moratorium indefinitely (2017 Pa. Laws 674, sec. 4 (adopted Oct. 23, 2017)). In view of the Commonwealth's prohibition, there are no mapped, developable unconventional gas resources in the Cooks Creek Watershed. In addition, the present rulemaking prohibits HVHF within the Delaware River Basin (*see,* 18 C.F.R. § 440.3(a)).

STATEMENT OF CONCERN (SC-58)

A commenter states that they can't drink from their well because it is contaminated due to hydraulic fracturing activity. They have to go to the neighboring town to fill up a 550-gallon tank and truck it back. Their well has been disconnected which has impacted the value/sale of their home.

RESPONSE (R-58)

Although DRBC is not in a position to comment on the cause of this specific case of contamination outside of the Delaware River Basin, the proposed regulations are intended to protect ground water and surface water drinking water supplies in the Delaware River Basin from pollution by activities associated with high volume hydraulic fracturing.

IMPACTS TO DRINKING WATER RESOURCES - SUMMARY

The Commission's responses to the numerous comments it received on potential impacts of HVHF to drinking water, based on the staff's careful evaluation of a decade of scientific data and literature on this subject, are summarized below:

- Risks to drinking water resources from high volume hydraulic fracturing and related activities include releases of chemicals and highly contaminated fluids from spills and accidents, migration of gas and other fluids, inadequate wastewater treatment, improper wastewater handling and disposal, wastewater reuse on roadways, excessive aquifer drawdown and reduced yield, and stream depletion.

- A large body of compelling scientific research has shown that the activities and materials associated with unconventional gas development can result in, and have resulted in, significant impacts to drinking water resources.

- Health effects associated with chronic oral exposure to HVHF chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity.

- Some fracturing fluid ingredients are claimed to be confidential business information (CBI) that can remain undisclosed to regulators and the public. Therefore, the possible presence of unknown chemical constituents in HVHF wastewater contributes to uncertainty about the effectiveness and potential impacts of management strategies, particularly with regard to toxicity, mobility, treatment efficacy and emergency management.

- Research has demonstrated that even with specialized treatment, the discharge of HVHF wastewater to surface waters can impact downstream drinking water supplies with the increased risk of disinfection byproduct formation. The PADEP amended Chapter 95 Wastewater Treatment Requirements (25 Pa. Code § 95.10) under the Clean Streams Law for new discharges of TDS in wastewaters (known as the 2010 TDS regulation), and in May of 2011, asked operators to stop discharging shale produced water to wastewater treatment plants that were exempt from the 2010 TDS regulation.

- The vulnerabilities of drinking water resources related to hydraulic fracturing can vary in frequency and severity depending upon multiple factors that are both within and beyond human control.

- The weight of evidence from several studies and data indicates that HVHF activities have adversely impacted private wells in Pennsylvania, and that proximity to gas wells is an important factor in the likelihood of such impacts.

- Comments minimizing the risks to drinking water resources are not consistent with the weight of the scientific evidence, the record of industry safety and compliance with regulations, and the recognition of other factors that contribute to the risks to drinking water resources.

- The Commission agrees with and relies on the EPA's understanding and interpretation of the peer-reviewed scientific research published through 2016; the EPA's conclusions that hydraulic fracturing activities can impact water resources under some circumstances; and EPA's finding that these impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors.

- After EPA issued its final report on Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States in 2016, additional research was published reinforcing EPA's conclusions and providing additional compelling evidence that HVHF may be accompanied by adverse impacts to water resources.

The Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, primarily: in rural areas dependent upon groundwater resources; in sensitive headwater areas considered to have high water resource values, in areas draining to DRBC Special Protection Waters, and in a region characterized by extensive geologic faults and fractures. Adverse impacts to drinking water would inevitably occur, as the result of spills, releases and discharges of harmful pollutants, including gas, salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined.

A decade of experience in other regions has shown that regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills, gas migration, and releases of chemicals and hydraulic fracturing wastewater. Accordingly, the Commission has determined that controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.3.2 Surface Waters and Aquatic Life

A large number of commenters expressed views about the impacts of high volume hydraulic fracturing activities on surface waters and aquatic life. Many expressed concerns that hydraulic fracturing activities would pollute streams and/or reduce stream flows, while many others opined that hydraulic fracturing can be and has been done safely and responsibly, and that concerns about potential impacts to surface waters and aquatic life are unfounded.

Statement of Concern (SC-59)

Representative comments supporting Section 440.3 of the rule and generally opposing hydraulic fracturing on the asserted grounds that it may impair surface water quality or streamflow are paraphrased below:

- The Delaware River was designated as part of the National Wild and Scenic Rivers System by Congress because of its outstanding features, irreplaceable resources, exceptional water quality and scenic and recreational values. These prized assets provide important economic benefit to all four states whose tributaries flow to the Delaware River. These values are gravely jeopardized by hydraulic fracturing and its polluting operations and must be protected for the public and future generations.

- The DRBC Water Code protects certain interstate waters of the Delaware River and its tributaries that have exceptionally high water quality, and which the Commission has designated as Special Protection Waters. The Code sets a management objective of "no measurable change except toward natural condition" for these waters. Natural gas extraction and its related activities have the potential to impair the quality of ground and surface waters that comprise or contribute to these exceptional quality waters.

- Recent studies have shown not only toxic pollutants of various kinds but very high radioactivity in HVHF waste. Accidents and leaks do happen, and we can't afford to let hydraulic fracturing happen in the Delaware River Basin.

- Substantial damage is caused by the toxic wastewater produced by hydraulic fracturing, which contains many dangerous pollutants, including naturally occurring radioactive materials, that cannot be fully removed by treatment, and those damages can substantially harm the water quality of our streams and the life in them.

- The infrastructure involved in fracking and waste disposal (well pads, pipelines, etc.) have consequences such as soil erosion and loss of riparian buffer zones that protect the quality of the water in the river.

- Portions of the DRB are sanctuary to rare and endemic species of plants and animals and home to the highest concentration of rare, threatened, and endangered species in Pennsylvania. Many of these plants and animals are extremely vulnerable to changes in habitat, stream flows, water chemistry, temperature, and turbidity that could result from the varied effects of unconventional natural gas development. Changes to stream water quality have been shown to occur where gas drilling and related activities are located.

Representative examples of comments opposing Section 440.3 of the rule and supporting hydraulic fracturing in the Delaware River Basin on the asserted grounds that it poses little risk to surface water quality, streamflow and/or aquatic life are paraphrased below:

- DRBC's proposal to prohibit HVHF operations in the Delaware River Basin is an extreme overreaction based upon either a misunderstanding or a misinterpretation of the most current and accurate information about the level of risk to surface water and groundwater sources from HVHF operations.

- The science and data clearly demonstrate that hydraulic fracturing can be and has been done safely and responsibly.

- SRBC data in PADEP possession indicate "no discernible impact" to the quality of water resources as a result of natural gas development.

- The potential risks to the environment posed by unconventional gas development are controllable and negligible and are offset by considerable potential benefits.

- Hydraulic fracturing operators have developed and implemented zero-discharge and controlled-collection well pad containments for use in sensitive environments to minimize the chances and consequences of the release of wastes generated by hydraulic fracturing.

Response (R-59)

The DRBC acknowledges and affirms those comments highlighting the Basin's outstanding water resources and the Commission's responsibility to manage these resources for continued human and ecological uses. The Commission appreciates the support expressed by many commenters for the regulations as an appropriate way to meet this responsibility. Although the DRBC also recognizes and appreciates industry's efforts to develop unconventional gas resources safely, for the reasons set forth below, we disagree that the regulations are an overreaction, that they are not based on current and accurate information about the risks to water resources posed by high volume hydraulic fracturing, and that the risks of this activity in the Delaware River Basin are controllable and negligible. The Commission accepts as thoroughly researched and accurately reported the EPA's conclusion in its 2016 report that hydraulic fracturing activities can impact water resources under some circumstances, and that these impacts can range in frequency and severity depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors (U.S. EPA, 2016a, p.

ES-3). After EPA issued this final report in 2016, additional research and data were published reinforcing EPA's conclusions and providing additional compelling evidence that HVHF may be accompanied by adverse impacts to water resources. Adverse impacts to surface waters and aquatic life water would inevitably occur as the result of planned or accidental discharges of harmful pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined.

DRBC fulfills the resource management charge conferred on it by the interstate and federal statute known as the Delaware River Basin Compact through policies, regulations and practices informed by science. As DRBC's policy set forth in its Comprehensive Plan and codified in the Delaware River Basin Water Code states:

> The quality of Basin waters, except intermittent streams, shall be maintained in a safe and satisfactory condition for the following uses:
>
> 1. agricultural, industrial, and public water supplies after reasonable treatment, except where natural salinity precludes such uses;
> 2. wildlife, fish and other aquatic life;
> 3. recreation;
> 4. navigation;
> 5. controlled and regulated waste assimilation to the extent that such use is compatible with other uses;
> 6. such other uses as may be provided by the Comprehensive Plan.

(Water Code, § 3.10.2 B).

The Commission's Comprehensive Plan and Water Code further provide that "it is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values." The Commission has designated such waters as "Special Protection Waters." The Commission acknowledges that hundreds of species thrive in the diverse stream, wetland, floodplain, and tidally-influenced habitats of the Delaware River Basin and that these include threatened and endangered species and those identified as Species of Greatest Conservation Need in the wildlife action plans of the four Basin states.

In 1968, Congress passed the Wild and Scenic Rivers Act. The Act "declared to be the policy of the United States that certain selected rivers of the Nation, which with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free- flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. ''

The DRBC cited this same passage in Docket No. D-78-51 CP, when it created a project docket to incorporate the designation of the Upper Delaware River as a component of the National Wild and Scenic River System into the DRBC Comprehensive Plan in accordance with Sections 11.1 and 13.1 of the Delaware River Basin Compact on July 26, 1978. Following the recommendations in the Final Environmental Impact Statement (NPS 1976) evaluating the designation of the river, the Commission declared that:

"The Governors of New York and Pennsylvania, jointly or through the Delaware River Basin Commission, and with the cooperation of local governments, take the lead in developing and implementing necessary land use control measures including adoption of flood plain and other zoning, building codes, standards for plant siting, utility rights-of-way, water and sewer line permits, etc., to assure (1) preservation of the existing environmental values in the river corridor, and (2) that permitted development within the corridor is compatible with designation of the river as a scenic and recreational river."

The DRBC later reaffirmed the inclusion of the Upper Delaware Scenic and Recreational River (UDS&RR) in the Comprehensive Plan. In revised DRBC Docket No. D-78-51 CP (March 23, 1988), the Commission made the decision that they "will consider the impact of a project on all areas within the boundaries of the Upper Delaware Scenic and Recreational River area to determine if such project impairs or conflicts with the Comprehensive Plan."

Congress designated the Upper Delaware River as part of the National Wild and Scenic Rivers System in recognition of its Outstandingly Remarkable Values (ORVs). ORVs are defined by the Wild and Scenic Rivers Act as the characteristics that make a river worthy of special protection and represent the resources and values that must be protected and enhanced. In order to be assessed as outstandingly remarkable, a value must be river-related and must be a unique, rare, or exemplary feature that is significant at a comparative regional or national scale. Within Upper Delaware Scenic and Recreational River, Middle Delaware Scenic and Recreational River, and Lower Delaware Wild and Scenic River these ORVs include exceptional water quality, free flow, ecological communities with high integrity, and outstanding water-based recreational opportunities (boating, fishing, scenic touring along the river) within close proximity to the most populated region of the United States.

The Commission's regulations, plans and policies have been developed and implemented over the course of nearly six decades to underpin and implement a comprehensive water resource management program or "Comprehensive Plan." *See* Compact, §§ 3.2(a) and 13.1. Although the long-term impacts of the shale gas industry on surface water and aquatic life are not yet fully understood, the scientific evidence to date, as set forth in detail below, makes clear that in those regions outside the Basin where high volume hydraulic fracturing has been intensively used to extract oil and gas from shale, this practice and the activities that accompany it have resulted in adverse impacts to surface waters and aquatic life that, were they to occur within the Basin, would significantly impair and impede the effectuation of the Commission's Comprehensive Plan and injuriously affect the waters of the Basin as contemplated by the Comprehensive Plan.

Risks And Impacts to Surface Waters and Aquatic Life

Assessing the potential for HVHF impacts to surface water and aquatic life requires an understanding of all phases of HVHF and supporting activities and an understanding of the hydrologic linkage between surface water and groundwater. The EPA's 2016 report describes in detail the risk to water resources of five stages of the "hydraulic fracturing water cycle," consisting of: water acquisition, chemical mixing, well injection, produced water handling, and wastewater disposal and reuse (U.S. EPA, 2016a, p. ES-9). The section of the report focused on natural gas well injection includes a discussion of well construction, the importance of mechanical integrity, and the implications of the loss of mechanical integrity as wells age.

The interaction between surface water and ground water is an important process that factors into the risks of HVHF activities to groundwater and surface water and is examined in studies of HVHF impacts. The interaction takes place two ways in the Basin; in most areas and under most conditions, streams gain water from the inflow of groundwater through the streambed; in other areas and/or under other conditions, streams lose flow to groundwater. Some streams do both, gaining flow in some reaches, and losing flow in other reaches. Streams can also gain flow under some conditions (such as low-flow conditions) and lose flow under other conditions (such as during flood events). As water flows between groundwater and surface water, contaminants can move with it. Contaminants in groundwater can be transported into adjacent surface water, and contaminants in surface water can be transported into adjacent groundwater. While surface water transport of contaminants is relatively rapid, the transport of contaminants through groundwater is usually very slow.

Risks to water resources at each stage of the hydraulic fracturing water cycle were identified in reports by the EPA (U.S. EPA, 2016a) and the NYSDEC (NYSDEC, 2015a, 2015b). Risks specific to surface water and aquatic life are noted in Table 8, adapted from these reports:

Stage of Hydraulic Fracturing	**Risks to Surface Waters and Aquatic Life**	**Potential Contaminant Transport Pathways**
Water acquisition	• Stream depletion	N/A
Chemical mixing	• Spills, leaks, and other releases	• Surface flow to surface water • Combinations of surface flow and subsurface flow
Well injection (includes activities associated with well construction, stimulation, production, and post-production)	• Migration of drilling fluids during construction; • Migration of gas and/or fluids from target formation to aquifers or streams; • Migration of gas from non-target formations to aquifers or streams; • Surface release of fluids (Blowouts, other equipment failures, interwellbore communications) • Sedimentation	• Surface flow • Combinations of surface flow and subsurface flow
Produced water handling	• Spills, leaks, and other releases	• Surface flow to surface water • Combinations of surface flow and subsurface flow

Wastewater disposal and reuse	• Inadequate treatment • Improper storage or disposal • Reuse for roadway de-icing or dust control	• Surface water discharge • Surface water runoff • Infiltration or subsurface discharge and subsurface migration

Table 8: Risks to Surface Waters and Aquatic Life at Each Stage of Hydraulic Fracturing Water Cycle

The risks noted in the table are described in greater detail below, as are the potential and documented impacts to surface waters and aquatic life that have been described in the scientific literature and agency reports.

WATER ACQUISITION — Each high volume hydraulic fracturing (HVHF) event utilizes millions of gallons of fresh water, and most of the water used is permanently removed from the hydrologic cycle. In Pennsylvania, the average amount of water used per event has increased from 7.46 million gallons to 16.04 million gallons as documented in an analysis of FracFocus Data for 2013-17 by ALL Consulting, LLC (ALL Consulting, 2018). Responses to other comments regarding water use for hydraulic fracturing are presented in Section 2.3.2.1, Water Use.

The likelihood of adverse effects of HVHF on regional surface water availability is low, as discussed in Section 2.3.2.1, Water Use. However, in the absence of constraints on the timing and location of large withdrawals, adverse impacts at the local scale, including diminished capacity to assimilate contaminants, are a concern, particularly during seasonal low-flow periods.

A study of the Susquehanna River Basin performed by the EPA showed that the potential for impacts to surface water quantity and quality as a result of HVHF water acquisition increases at finer temporal and spatial resolutions (U.S. EPA, 2015b, p. 1). The study determined a surface water use intensity index, calculated as the sum of withdrawals for HVHF in a watershed on a given day, divided by the total surface water available (equated with streamflow at the watershed outlet on that day). The index is a measure of the impact of the withdrawals on streamflow for a particular watershed. The index was evaluated at different scales to determine how impacts vary with watershed size. Analysis of this metric showed that for HVHF withdrawals during 2009-2013, the surface water use intensity index did not exceed a value of 0.1 for watershed areas greater than 27 mi^2, meaning that for these larger watersheds, HVHF withdrawals did not exceed 10 percent of streamflow on any given day. Index values exceeded 0.2 only in the smallest watersheds of less than 7.8 mi^2. The Susquehanna River Basin Commission regulates water acquisition and issues permits to operators for individual withdrawal sites. The permits assign daily withdrawal and pumping rate limits and set river passby flow thresholds that halt withdrawals during periods of low flow. The EPA study also showed that higher withdrawal rates and larger index values would have been observed on many occasions if the passby flow thresholds had not been in place. This result indicated that the SRBC's regulations were effective in reducing HVHF impacts on streamflow.

The EPA study also conducted an analysis of the potential impact of reduced streamflows on water quality by calculating the value of "concentration magnification" from the surface water use intensity index. Results showed that for watersheds larger than 200 mi^2, pollutant concentrations would increase 10 percent or less – and usually, 1 percent or less – due to reduced water volume. Water quality was more vulnerable to withdrawals in watersheds smaller than 20 mi^2, where in some instances pollutant concentrations increased by factors ranging from 2–10. The report noted that effluent discharges might be less frequently permitted on such vulnerable streams. At a representative public water supply in Bradford County and a private wellfield in Wyoming County, the study also examined the potential for groundwater withdrawals to result in localized impacts due to aquifer drawdown and baseflow depletion. The study did not find any observed or reported impact from hydraulic fracturing water acquisition on local domestic wells, and baseflow depletion was less than 10 percent under average flow conditions. A study by Yale University within the Pennsylvania Marcellus region similarly concluded that flow alteration from HVHF activity varies inversely with watershed area (Barth-Naftilan *et al.,* 2015).

A study by SBRC and Penn State University examined effects of HVHF withdrawals on fish and macroinvertebrate assemblages in the Susquehanna River Basin (Shank and Stauffer, 2015). Regression models indicated that catchment-level variables other than withdrawals explained most of the variation in fish metrics, and variations in macroinvertebrate metrics were not explained by any of the variables considered. The researchers concluded that impacts of shale gas withdrawals on fish and macroinvertebrates within the Susquehanna River Basin were limited and that the withdrawals were not impacting fish and macroinvertebrate assemblages to a greater degree than other watershed variables. Possible reasons for this conclusion are the success of pass-by flow restrictions in limiting impacts of withdrawals and in some instances the relatively recent initiation of withdrawals within the previous three years.

CHEMICAL MIXING – The chemical mixing stage includes the mixing of base fluid (90 percent to 97 percent by volume, typically water), proppant (2 percent to 10 percent by volume, typically sand), and additives (up to 2 percent by volume, typically less than 0.5 percent) on the well pad to produce the fluid used for hydraulic fracturing. This fluid is engineered to create and extend fractures in the targeted formation and to carry proppant into the fractures. Concentrated additives, often including biocides, are delivered to the well pad and stored on site, often in multiple, closed containers, and moved around the well pad in hoses and tubing (U.S. EPA, 2016a, p. ES-22). Many chemicals from hydraulic fracturing activity are known to be hazardous (meaning they are carcinogenic, endocrine disrupting, produce adverse immune or nervous system effects, and/or are toxic to reproductive and developmental systems); however, not all of the chemicals and additives used in hydraulic fracturing have been identified, and only a subset of the identified substances have established toxicity values, according to the EPA (U.S. EPA, 2016a, p. ES-43). Despite these uncertainties, depending on the concentrations and synergistic effects of chemicals during exposure, the known properties of substances used and generated by hydraulic fracturing and their potential human health effects include toxicity to multiple human organs, sensitization, irritation, developmental effects, and tumor promotion (Kassotis *et al.,* 2018). Additional information about chemicals used in hydraulic fracturing is presented in Section 2.3.2.2, Pollution from Spills.

Risks to surface waters and aquatic life during the chemical mixing stage of HVHF include spills, leaks, explosions and other fluid releases that can flow into surface waters. The Commission acknowledges that the industry has developed measures that, when implemented properly, can reduce the potential for fluid releases. These include zero-discharge and controlled-collection well pad containments. The investment in such approaches is evidence in and of itself of the risks posed by spills. Despite their deployment, however, impacts on groundwater or surface water due to overflows, liner breaches, tank corrosion and leakage, casing, hose, or pipeline ruptures, fires, and other construction and equipment issues have been documented (Frazier, 2017a; PADEP, 2017c; PADEP, 2016b; PADEP, 2016c; PADEP, 2016d; U.S. EPA, 2016a, p. 8-43; PADEP, 2014b; PADEP, 2014c; U.S. EPA, 2014; Williamsport Sun-Gazette, 2014; Considine *et al.,* 2012; Detrow, 2012; MDN, 2012; Gilliland, 2011; Legere, 2011). A 2019 study estimated that the likelihood of impacts to surface water from spills resulting from HVHF activity at the well pad is as high as 1 in 10 per well (Shanafield *et al.,* 2019). Some examples of spill incidents that resulted in impacts to surface water and/or aquatic life are presented below in the discussions of well injection and produced water handling. Responses to additional comments regarding spills, including frequency of spill occurrences, are presented in Section 2.3.22, Pollution from Spills.

WELL INJECTION – The well injection stage involves the injection of hydraulic fracturing fluids through the production well and their movement in the production zone. This stage also includes activities at the well site before and after injection, including well construction, production, and post-production. During the process of well injection, the fluid mixtures described above are pumped into the well at high pressure. The pressure is increased until it exceeds the formation strength and fractures the rock. Equipment failure during fracturing operations can result in the release of HVHF fluids as well as formation waters. Some examples are presented below:

- On April 19, 2011, a well head failure during hydraulic fracturing on a Chesapeake Energy well pad in Bradford County, PA, allowed thousands of gallons of HVHF fluid to flow onto the pad, overwhelm multiple containment measures, and discharge into a tributary (Towanda Creek) to the Susquehanna River. Reports of the incident noted that the event occurred despite 'careful measures' being implemented by the operator, which underscores the potential for catastrophic failure despite best intentions, planning and practice exercised in the industry. A release of 21,000 gallons of production fluid was spilled within Pennsylvania State Forest lands and resulted in the death of amphibians in a local pond (Considine *et al.,* 2012; Natural Gas Intelligence, 2011; Gilliland, 2011).

- A catastrophic fire in 2014 at the Eisenbarth well pad in Clarington, Ohio consumed the contents of the well pad, which included more than 25,000 gallons of products that were staged and/or in use. Among the materials were 3,300 gallons of tributyl tetradecyl phosphonium chloride (TTPC), a biocide; three Cesium-137 radiological sources; 7,000 gallons of GasPerm 1000 microemulsion surfactant product; and more than 11,000 gallons of petroleum distillates. As a result of fire-fighting efforts and uncontrolled flowback from one of the eight wells at the site, significant quantities of water and unknown quantities of materials stored on the well pad left the site and entered an unnamed tributary of Opossum Creek, a tributary to the Ohio River. The Ohio Department of Natural Resources (ODNR) reported an estimated 70,000 dead fish from an approximately 5-mile reach of the unnamed tributary (U.S. EPA, 2014).

- An explosion at an XTO-owned well pad near Powhatan Point, Ohio on February 15, 2018 damaged the wellhead and caused the loss of control of the well for 19 days. The accident resulted in the uncontrolled release of over 5,000 gallons of HVHF fluid into a tributary of the Ohio River (DiSavino and Palmer, 2018; Grant, 2018; 2018; U.S. EPA, 2018a) and by EPA's estimate, 2 billion cubic feet of natural gas to the atmosphere (Grant, 2018). The cause of the incident was reportedly a pressure buildup that resulted in the failure of a well casing (Grego, 2019). This incident is noteworthy because it occurred in 2018, following several years of progress in the development of industry standards and best practices, resulting in what API described (one month after the incident) as "significant improvements to system integrity, reliability, and integrated safety." (API, 2018, pp. 1-2)

- Gas leaking from defective production wells can migrate to shallow groundwater and to streams and can be observed to bubble up from the impacted streambed (Grieve *et al.,* 2018; Llewellyn *et al.,* 2015). Geochemical analyses of water from one stream with high methane (Sugar Run, Lycoming County) were found by the U.S. Geological Survey to be consistent with Middle Devonian gases (Heilweil *et al.,* 2014). The stream is near the location of a PADEP investigation of suspected stray-gas migration from a nearby Marcellus Formation gas well. One-dimensional stream-methane transport modeling by USGS was used to quantify the amount of methane entering the stream. Results indicated a groundwater thermogenic methane flux of about 0.5 kilograms per day discharging into Sugar Run. Another investigation of 131 stream sites in Pennsylvania found methane concentrations in 12 of the sites were above a threshold of 4 µg/l, indicating sources such as leaking gas wells, shallow organic-rich shales, coal, or landfills (Wendt *et al.,* 2018). Additional investigation combined data for over 500 streams in Pennsylvania, New York, and West Virginia and found 128 sites with elevated methane. The study also documented the phenomenon of "gas leak drainage" (GLD), whereby hydrocarbons from leaking gas wells change the subsurface redox environment such that metals are mobilized, and hydrogen sulfide is produced. The impacted groundwater can discharge to the surface as GLD A consequence is visible rust-colored methane- and metal-rich springs (not located near coal mining and chemically distinct from abandoned mine drainage) that flow into and impact nearby streams (Woda *et al.,* 2019).

Another risk during fracturing operations is interwellbore communication, in which induced fractures intercept a nearby well with possible flow of fluids from one wellbore to another, as in the incident described below.

- On January 13, 2012 in Garrington, Alberta, a horizontal well was being stimulated, and a communication pathway was created between the stimulated horizontal well and a vertical well producing from the same formation 432 feet away. The opening of this pathway resulted in fluids migrating from the stimulated well to the nearby producing well and the uncontrolled released of hydraulic fracturing fluid and formation fluids to the surface through the vertical well. An estimated 75 cubic meters (about 20,000 gallons) of fluids were released. The cause of the incident was the flawed design of the horizontal well stimulation. According to the provincial regulator, the spilled fluids were contained, and the incident did not impact groundwater or surface waters (ERCB, 2012).

In 2016 the PADEP adopted regulations to address communication with offset wells. Other risks related to the well injection stage of the hydraulic fracturing water life cycle are presented in Section2.3.2.3, Pollution from Fluid Migration.

The activities and materials associated with the chemical mixing and well injection phases of HVHF can and have resulted in significant impacts to surface waters and aquatic life.

PRODUCED WATER HANDLING — Produced water is a waste generated during shale gas production, and it flows to the surface through the production well, along with gas. It consists of initial flowback of a portion of the fracturing fluids injected into the wellbore and formation fluids. Operators must capture, store, treat, and/ or dispose of large amounts of produced water, either on site or off site. Produced water from hydraulic fracturing activities has been found to contain components of the fracturing fluid and sub-surface contaminants including, among others:

- Salts, including those composed from chloride, bromide, sulfate, sodium, magnesium, and calcium;
- Metals, including barium, manganese, iron, and strontium;
- Naturally occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes (BTEX), and oil and grease;
- Radioactive materials, including radium; and
- Hydraulic fracturing chemicals and their chemical transformation products (U.S. EPA, 2016a, p. ES-33).

Releases of produced water and/or fracturing fluids from hydraulic fracturing activities can adversely impact and have impacted surface waters and aquatic life. These effects can be conspicuous in spill incidents that result in releases to waterways. Some examples are described below:

- During the development of four natural gas wells in 2007 in Kentucky, HVHF fluids were released into Acorn Fork, a designated Outstanding State Resource Water and habitat for a threatened fish species, the Blackside Dace. As a result, stream pH dropped, stream conductivity increased abruptly and persistently, and aquatic invertebrates and fish, including the Blackside Dace, were killed or distressed (Papoulias and Velasco, 2013).
- In 2009, a leak in an overland pipe carrying a mixture of flowback and freshwater between two HVHF impoundments in Pennsylvania released approximately 11,000 gallons of fluids into an unnamed tributary of the Ohio River, affecting a 0.6 km length of the stream, in which fish and salamanders were killed (U.S. EPA, 2016a, p. 7-26).
- In 2010, inspectors observed an unpermitted discharge from an open valve at an XTO-operated recycling plant in Penn Township, Lycoming County. HVHF produced water flowed through the open valve, into a drainage swale, off the pad, and eventually impacted an unnamed tributary to the Susquehanna River and a spring. The volume of fluid released was estimated to range from between 534 to 1,366 barrels. 528 tons of contaminated soil were removed from the drainage swale. Investigation and sampling by EPA and PADEP found elevated levels of chloride, barium, strontium and total dissolved solids in the tributary stream as a result of the discharge. The PADEP assessed XTO a civil penalty of $300,000 (PADEP, 2016c; Marczak, 2013).
- In 2014, a spill of produced water at a well pad in Tyler County, West Virginia resulted in surface water contamination for more than one month, as confirmed by surface water sampling adjacent to the spill site (Harkness *et al.,* 2017).

- During 2012-14, multiple HVHF fluid releases occurred through overflows or holes in liners of eight centralized impoundments owned and operated by Range Resources Appalachia LLC in Washington County, PA. The releases impacted three tributaries of the Ohio River. In addition to a civil penalty of $4,150,000, the PADEP-issued Consent Order and Agreement required impoundment closure or upgrades, and remediation of contaminated areas (PADEP, 2014c).

- In 2015 a pipeline leak discovered near Williston, North Dakota released nearly 3 million gallons of produced water from hydraulic fracturing operations into a tributary of the Missouri River over a period of at least three months. Following the initiation of remediation efforts, the U.S. Geological Survey led an investigation of the downstream effects of the spill. Geochemical and biological sampling downstream from the spill site found numerous persistent effects, including boron and strontium concentrations and radium activities in sediment up to 15 times background, reduced fish survival, and estrogenic inhibition. The findings demonstrate that "environmental signatures from HVHF wastewater spills are persistent and create the potential for long-term environmental health effects." (Cozzarelli *et al.,* 2017). Inorganic contamination at other spill sites in North Dakota was also persistent, with contaminants observed at spills sites up to four years following the spill events (Lauer *et al.,* 2016). The impacts from sequential spills to the same streams may be even more persistent: microcosm studies of biocides commonly used in HVHF (glutaraldehyde and DBNPA) indicated that after streams have been impacted by either of these biocides, microbial community changes can affect degradation dynamics, such that future impacts may persist even longer than they would in previously unimpacted streams (Campa *et al.,* 2019; Campa *et al.,* 2018).

- Not only have scientists and the PADEP found contamination of surface and ground water sources as a result of HVHF-related spills in Pennsylvania, but so has at least one Pennsylvania court. In *Kiskadden v. PADEP*, Judge Wojcik wrote in reference to the Yeager site, a HVHF waste impoundment operation in Washington County, PA cited for numerous violations of state laws regulating oil and gas, solid waste management, clean streams, and dam safety and encroachment: "[T]here is little dispute that the activities at the Yeager Site impacted the environment and contaminated the soil and adjacent springs . . . ." *Kiskadden v. Pa. Dep't of Envtl. Prot.*, 149 A.3d 380, 403 (Pa. Cmwlth. 2016).

Following a multi-year grand jury investigation of HVHF impacts, the Pennsylvania Attorney General brought criminal charges against Yaeger site leaseholder Range Resources for negligent oversight, to which the company pleaded no contest (Phillis, 2020). Notably, as of October 8, 2016, the use of centralized impoundments to store unconventional well wastewater is allowed in Pennsylvania only if the operator obtains a residual waste storage permit from the Department. *See* 25 Pa. Code § 78a.59c. Responses to additional comments regarding spills are presented in Section 2.3.2.2 (Pollution from Spills) of this Comment and Response Document.

The activities and materials associated with the produced water handling phase of HVHF can and have resulted in significant impacts to surface waters and aquatic life.

WASTEWATER DISPOSAL AND REUSE – This final stage of the hydraulic fracturing water cycle consists of the management of wastewater, including disposal, recycling and reuse in hydraulic fracturing operations, and other reuses. Until 2011, much of the produced water generated by HVHF in

Pennsylvania was treated inadequately at publicly owned treatment works (POTWs) and discharged to surface water. Adverse impacts in the receiving waters from these discharges have been documented. Following the discontinuation of this practice, effluent quality from the POTWs improved (Ferrar *et al.,* 2013), but other means of disposing of HVHF wastewater were needed. The PADEP amended Chapter 95 Wastewater Treatment Requirements (25 Pa. Code § 95.10) under the Clean Streams Law for new discharges of TDS in wastewaters (known as the 2010 TDS regulation), and in May of 2011, asked operators to stop discharging shale produced water to wastewater treatment plants that were exempt from the 2010 TDS regulation because of water quality concerns downstream of municipal discharge points (PADEP, 2011). While to the best of our information POTWs are at present complying with the PADEP request, no law or regulation fully prohibits all discharges. The federal government (EPA) has signaled a desire to expand discharge options (*see* U.S. EPA, 2019). Under 25 Pa. Code § 95.10 new and expanding treated discharges of wastewater resulting from hydraulic fracturing may be authorized by the PADEP, provided that requirements regarding effluent concentrations are met. Details about these requirements are provided in Section 2.3.2.4, Pollution from Wastewater Treatment and Disposal.

Presently, most of the HVHF wastewater produced in Pennsylvania is recycled to hydraulically fracture other wells or is transported to other states for disposal through deep well injection. However, some HVHF wastewater is treated at centralized waste treatment facilities (“CWTs” or “CWT facilities”) in Pennsylvania, and CWT effluent discharges have generated numerous environmental problems as described in this section and in Section 2.3.3.1, Drinking Water Resources. The use of CWT facilities in Pennsylvania could increase in the future in response to changing circumstances (U.S. EPA, 2019).

Studies in suspected impact areas downstream from CWT discharges and spills have documented the various effects that even treated wastewater from HVHF activities can have, and have had, on surface water quality and aquatic life. A 2013 study focused on the impacts to background water quality in a western Pennsylvania stream caused by CWT discharges. The study showed that the discharge from a CWT exclusively treating oil and gas wastewaters increased downstream concentrations of chloride and bromide to above background levels. Chloride concentrations 1.05 miles (1.7 km) downstream from the treatment facility were 2 to 10 times higher than the background chloride concentrations observed in western Pennsylvania reference streams. Levels of $_{226}$Ra in stream sediments (544–8759 Bq/kg) at the point of discharge were approximately 200 times greater than in upstream and background sediments (22–44 Bq/kg) and above radioactive waste disposal threshold regulations, posing potential environmental risks of radium bioaccumulation in localized areas of shale gas wastewater disposal. Bioaccumulation of radium is known to occur in freshwater fish, invertebrates, mollusks, and shells, with reported concentration factors of 100-1000 (Warner *et al.,* 2013a).

A 2018 EPA report on centralized waste treatment for managing oil and gas extraction wastes described documented and potential human health and environmental impacts of discharges from CWT facilities managing conventional and unconventional oil and gas extraction wastewater (U.S. EPA, 2018b). Results of analysis of effluent and stream monitoring data (including data collected prior to the 2011 PADEP request to operators described above) clearly show that CWTs accepting oil and gas extraction wastes were not operating with adequate treatment for these wastes, and discharges from CWT facilities accepting oil and gas extraction wastes had the potential to contribute to a range of human health and environmental impacts. The EPA’s 2018 study attempted in part to determine if the existing EPA regulations governing CWTs should be updated, specifically in regard to facilities that accept oil and gas extraction wastes. Among the many topics covered, the study examined total dissolved solids (TDS) concentrations in upstream waters, CWT effluent, and downstream waters. Results, shown in Figure 14, reveal that TDS concentrations of most samples collected in downstream waters were above the EPA's Secondary Maximum Contaminant Level (SMCL) of 500 mg/l, which can be harmful to freshwater aquatic life. Similarly, reported effluent and downstream concentrations of chloride, bromide, metals, and TENORM were also higher than upstream concentrations. These results demonstrate unequivocally that CWT discharges of treated HVHF wastewater can adversely impact, and have adversely impacted, surface waters.

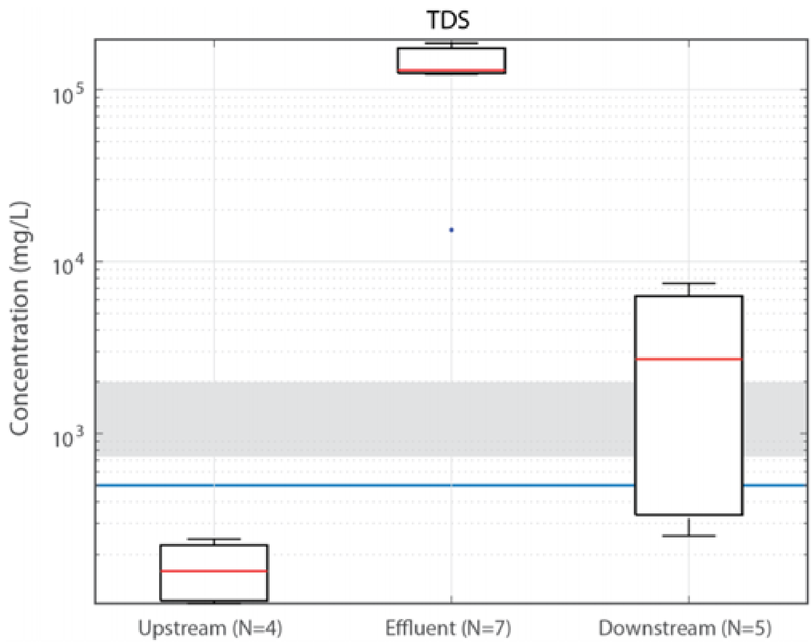

Figure 14: TDS Concentrations from Sites Upstream of Effluent Discharge, Effluent from Facilities Treating O&G Wastewater, and Downstream of Discharge Sites.
Source: EPA, 2018b

Conclusions of the EPA study include the following:

- "EPA approved analytical methods do not exist for many constituents found in oil and gas extraction wastes. In addition, some constituents (such as total dissolved solids) found in oil and gas extraction wastes can interfere with EPA approved analytical methods and significantly affect the ability to detect and quantify the level of some analytes."

- "Levels of pollutants downstream from CWT facility discharges have been reported to exceed applicable thresholds, such as primary and secondary drinking water standards and acute and chronic water quality criteria for protection of aquatic life."

- "CWT effluents have been shown to adversely affect downstream aquatic life."

Other details of the 2018 EPA study are presented in Section 2.3.3.4, Pollution from Wastewater Handling and Disposal and Section 2.3.3.1, Drinking Water Resources.

A regional study of effects of HVHF activities on chloride and total suspended solids (TSS) in the Marcellus Shale watersheds of Pennsylvania suggested that the presence of CWT discharges in a watershed increased chloride concentrations downstream, and that the presence of HVHF wells in a watershed increased downstream TSS concentrations. The CWT discharges were presumed to be the contaminant pathway for chloride. The contaminant pathway for TSS from well pads was not evident from the results because an increase in TSS impact was not observed during precipitation events or during well pad construction (Olmstead *et al.,* 2013).

Studies using environmental markers have documented historical impacts to surface water quality from the discharge of treated HVHF wastewater by CWTs. A geochemical study of sediment cores and porewater collected in 2015 from the bottom of the Conemaugh River Lake, a reservoir located downstream from two CWT facilities in western Pennsylvania, showed surface water impacts from the disposal of HVHF wastewater during 2006-2011. The two CWT facilities are located 6.2 and 11.8 miles (10 and 19 km) upstream from the reservoir, respectively. Annual contaminant loads of barium, chloride, and total dissolved solids (TDS) from the facilities were calculated from compliance data to document the intensity and timing of industrial activity contributing the discharged wastes. Sections of cores and paired porewater samples were analyzed for a variety of constituents to identify evidence of deposition from HVHF wastewater. Sediment layers corresponding to the years of maximum wastewater discharge contained higher levels of salts, alkaline earth metals, and organic chemicals. Sediment concentrations of barium were high enough to possibly threaten the quality of neighboring groundwater. Analysis of isotopes of radium and strontium determined that the likely source of peak concentrations of Ra and Sr were wastewaters originating from the Marcellus Shale. The unconventional oil and gas wastewater signal was likely derived from a small volume of HVHF wastewater relative to the volume of the stream but the HVHF wastewater nonetheless had a measurable impact. The study demonstrates that effluent from CWT facilities treating HVHF wastewater can result in, and has resulted in, persistent sediment contamination many miles downstream (Burgos *et al.,* 2017).

Another study used the accumulation of metals in the shell material of bivalves as a marker to trace historical upstream wastewater discharges (Geeza *et al.,* 2018). Bivalves precipitate a shell of carbonate that can be used as a proxy for a variety of water quality parameters such as temperature, pH, and salinity. Carbon, oxygen, and strontium isotopes in shell material can be used to reconstruct water quality conditions, trace environmental contaminants, and observe cyclic variations in water chemistry. The research team, led by Penn State University, examined the accumulation of metals in the shells of freshwater mussels collected upstream and downstream of a CWT facility, as well as from the Juniata and Delaware Rivers that had no reported upstream oil and gas wastewater discharge. Observed changes in the ratios of strontium/calcium and in strontium isotope ratios in shells collected downstream from the discharge corresponded to the time of the greatest intensity of Marcellus Shale gas wastewater disposal (2009-2011). The changes in these ratios also shifted toward values characteristic of wastewater produced from development of the Marcellus Shale. Shell material collected upstream of the CWT facility and from the rivers without oil and gas wastewater discharges showed lower variability and no trend in either ratio over the 2008-2015 period. The findings suggest that freshwater mussels acted as chemical recorders of HVHF wastewater contaminants in waterways and that wastewater contaminants likely bioaccumulated in areas of surface disposal. The layers of shell created after 2011 (when the PADEP asked operators to stop discharging shale produced water to wastewater treatment plants that were exempt from the 2010 TDS regulation) did not show an immediate reduction in the concentration of strontium corresponding to the reduction in HVHF wastewater discharged after 2011. Instead, the change appeared gradually, suggesting that higher concentrations of metals and other HVHF contaminants persisted in the sediment in the mussel habitat. The study results show that impacts from HVHF wastewater discharges on river sediments and biota can be persistent and that even discharges of short duration may leave a long legacy.

The PADEP conducted aquatic biology investigations at sites upstream and downstream from two facilities that treated industrial waste produced by conventional oil and gas wells. The facilities discharged the treated effluent to the Allegheny River in Warren County PA. Results from the analysis of water, sediment, and macroinvertebrate sampling demonstrated negative impacts to water quality, sediment, and macroinvertebrate communities from the upstream discharges of treated oil and gas wastewater. Results of resampling conducted after the cessation of the discharges showed improvements in macroinvertebrate indices and a suite of water-quality parameters that included inorganics and metals. The resampling studies did not include sediment sampling or radionuclide analysis that would have indicated whether there had been improvements in sediment quality or radionuclides (Brancato, 2013; Brancato, 2015a-c; Brancato, 2016; Brancato, 2017). Results of a USFWS/USGS study on the downstream effects of these discharges demonstrated negative impacts on the survival of a federally endangered mussel species (northern riffleshell) and on the abundance and diversity of a native mussel species (unionid) (Patnode, 2015). Details of this study are presented in the section below on Impacts to Aquatic Life.

Although few deep well injection facilities for the disposal of HVHF produced water are currently operating in Pennsylvania (PADEP, 2018b), the potential for surface water and aquatic life impacts from these facilities should be noted. The potential risks of this method were evaluated through an intensive, interdisciplinary study conducted in 2014 by the U.S. Geological Survey at an injection disposal facility in West Virginia. Surface water samples collected downstream from the site had elevated specific conductance (416 μS/cm compared to 74 μS/cm upstream), and sodium, chlorine, barium, bromine, strontium, and lithium concentrations all were elevated compared to upstream, background samples. Elevated TDS, a marker of HVHF wastewater, provided an early indication of impacts in the stream. Wastewater inputs were also evident by changes in ${}_{87}Sr/{}_{86}Sr$ in stream samples collected adjacent to the disposal facility, and by organic compounds linked to HVHF found in stream water and sediments. Sediments downstream from the facility were enriched in Ra and had high bioavailable Fe(III) concentrations relative to upstream sediments. Microbial communities in downstream sediments exhibited lower diversity and shifts in composition. Water downstream had significantly more endocrine disrupting chemical (EDC) activity than reference water upstream, and antagonist activities in downstream samples were at equivalent authentic standard concentrations known to disrupt reproduction and/or development in aquatic animals. Although the hydrologic pathways of contaminant migration could not be assessed, these data provide strong evidence demonstrating that activities at the deep well disposal facility were impacting a nearby stream and altering the biogeochemistry of nearby ecosystems (Orem *et al.,* 2017; Akob *et al.,* 2016; Kassotis *et al.,* 2016).

The spreading of oil and gas wastewaters on roadways for deicing or dust suppression is another means by which HVHF activity may impact water resources and aquatic habitats. From July 2009 to June 2010, about 13,000 gallons of Marcellus Shale hydraulic fracturing wastewater was reported to be spread on roads in Pennsylvania (Rozell and Reaven, 2011). Road spreading of brine from unconventional wells is explicitly forbidden by current Pennsylvania's regulations *See*, 25 Pa.Code §§

78a.70 and 78a.70a. A 2018 study led by Penn State University found that oil and gas wastewaters spread on roads in the northeastern U.S. have salt, radioactivity, and organic contaminant concentrations often many times above drinking water standards (Tasker *et al.,* 2018). The study also found that in Pennsylvania from 2008 to 2014, spreading oil and gas wastewater on roads released over 4 times more radium to the environment (320 millicuries) than oil and gas wastewater treatment discharges and 200 times more radium than spill events. Lab experiments demonstrated that nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water. Currently, state-by-state regulations do not require radium analyses prior to treating roads with oil and gas wastewaters. Additional detail about roadway spreading is presented in Section 2.7.7 (Application of Hydraulic Fracturing Produced Water/Wastewater).

The activities and materials associated with the wastewater disposal and reuse phases of HVHF can and have resulted in significant impacts to surface waters and aquatic life.

Additional responses to comments on wastewater handling and disposal are presented in Section 2.3.3.4.

Regional Impacts to Surface Waters

Statewide data on violations of the Pennsylvania Clean Streams Law (CSL) provide one indication of the extent to which HVHF activities are resulting in impacts to surface waters. Figure 15, constructed from PADEP Oil and Gas Reports, shows annual total CSL violations for unconventional wells spudded during 2008-2018. The number of recorded CSL violations decreased for five successive years after 2010, as the number of unconventional wells spudded declined, but increased again after 2015, as the number of unconventional well spuds began to climb. Figure 16 shows the number of CSL violations per unconventional well spudded during 2008-2018. This statistic shows a decreasing trend during 2010-2014 and an increasing trend in violations during 2014-2018. In 2014, the number of CSL violations per well spud was 0.05, or an average of one violation per twenty well spuds. In 2018, the number of CSL violations per well spud had increased to 0.28, or one violation per 3.6 well spuds. The PADEP changed the way it recorded violations, which may have contributed to the latest period of recorded increase.

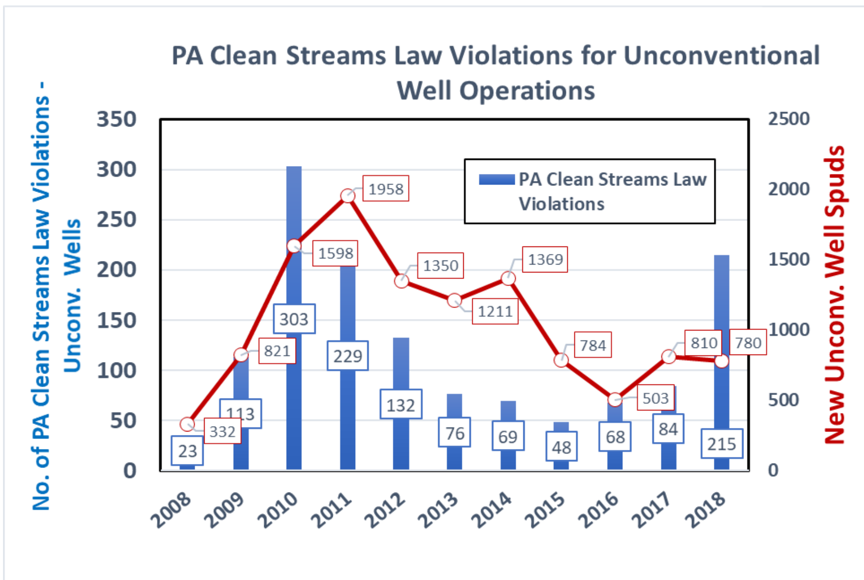

Figure 15: Annual PA Clean Streams Law violations for unconventional wells spudded during 2008-2018
(data compiled from PADEP Oil and Gas Reports)

The effects of HVHF fluid and wastewater releases on surface waters and aquatic life are noted concerns of many commenters. Some scientific studies of HVHF impacts to surface waters examine water quality at a broad scale and seek to determine the extent to which various factors, including the presence of HVHF activities, explain the observed variability in water quality or biotic metrics. At a regional scale, the impact of HVHF activities on surface water quality in the Appalachian region has been difficult to determine conclusively because baseline conditions are often unknown, or because impacts that have already resulted from other activities, such as coal mining and other human activities, may be masking any effects of HVHF. The Susquehanna River Basin Commission examined trends in water quality in the Susquehanna River Basin and found an increasing trend in specific conductance at 24 stations based on three to six years of data collected at 53 monitoring stations (SRBC, 2017). However, watershed characteristics (including natural gas well density) for monitoring stations with increasing conductance trends were not statistically different from those of stations with no observable trend. The section of the report entitled "Next Steps," includes the following statement:

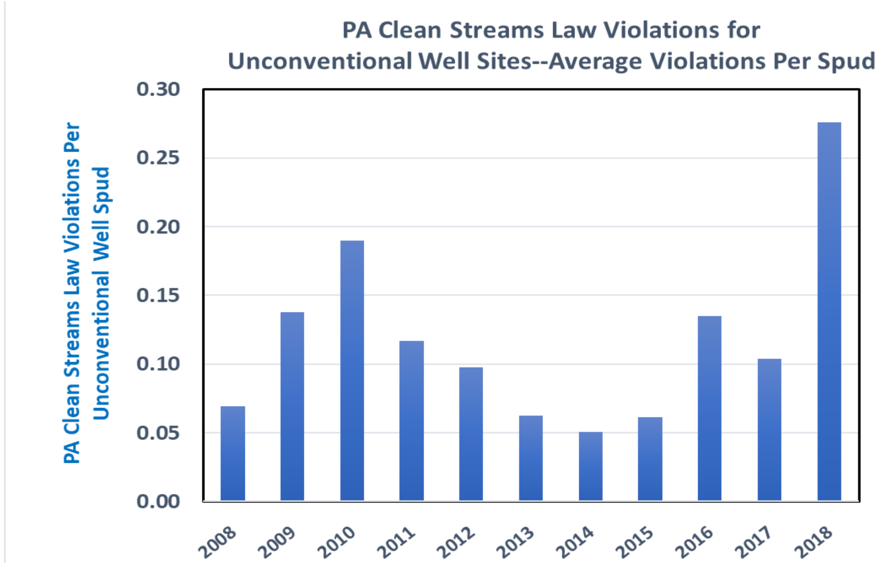

Figure 16: PA Clean Streams Violations for unconventional well sites - average violations spud, 2008-2018
(data compiled from PADEP Oil and Gas Reports)

> To date, the Commission's remote water quality monitoring network has not detected discernible impacts on the quality of the Basin's water resources as a result of natural gas development, but continued vigilance is warranted. The Commission's next steps with the program include selecting a subset of stations with increasing conductance trends to further investigate the cause of increasing conductance.

A 2016 study by the Northeast-Midwest Institute and the U.S. Geological Survey found that current basin-wide water quality monitoring in the Susquehanna River Basin is inadequate for determining if shale gas development activities systematically contaminate surface waters or groundwater (Betanzo *et al.,* 2016).

A 2019 report by the SRBC describes results from the SRBC Remote Water Quality Monitoring Network (RWQMN) for 16 selected stations (from the full network of 59 stations) in watersheds that drain portions of, or that flow through, state forest lands (Berry, 2019). The report has been cited as evidence of no impact from HVHF activity (Shepstone, 2019). The Commission disputes this contention, as the results presented in this report are inconclusive regarding impacts of HVHF activity. More details about SRBC's 2016 and 2019 monitoring reports are presented in Section 2.6.5 (SRB Policies and Reports).

The PADCNR Bureau of Forestry partnered with SRBC and others to conduct additional water-quality monitoring of streams in Pennsylvania state forest lands where HVHF activities have occurred. More than 97 percent of forest land within the Pennsylvania core gas forest districts are within the Susquehanna River Basin. A report on these monitoring efforts concluded in part:

> Water quality monitoring efforts by the bureau and its partners have not raised significant concerns on state forest headwater streams to date. However, these are still relatively short-term results and may not be indicative of long-term or cumulative effects that can only be detected through long-term monitoring efforts.

(PADCNR, 2018).

Although the SRBC reports are inconclusive, a 2019 study by American University provided evidence of regional HVHF impacts in southwestern Pennsylvania, primarily within the Ohio River drainage. The statistical analysis of water quality in streams in southwestern Pennsylvania and western Maryland concluded that an index of oil and gas development had significant explanatory power for variability in specific conductance, arsenic, strontium, and other cations. The study also found that other land use and land cover variables (forest, urban development, coal mining) as well as stream discharge and pH were also significantly associated with water quality variables. The results of this study imply that water quality has been affected by oil and gas development in at least some areas of the Marcellus Shale region. The study design could not identify the causal mechanisms through which oil and gas development affects water quality constituents (Knee and Masker, 2019).

As part of a USGS study of water quality in the Monongahela River Basin in West Virginia during July through October of 2012, fifty stream sites in subbasins were sampled under base-flow conditions. Concentrations of fluoride and barium were higher in stream subbasins that were near active HVHF production than in subbasins that were either not near active HVHF production or that had HVHF production within the subbasin. Elevated fluoride and barium are associated with deep brines. Water quality results were also compared with historical data, which indicated higher concentrations of chloride and strontium and higher pH values in the survey samples. Possible pathways for deep-brine constituents to surface waters include upward migration of brines through faults and fractures, upward migration of brines along improperly constructed or sealed gas wells, and accidental discharge of well brines to surface waters. Additional study would be needed to further interpret these results (Chambers *et al.,* 2015).

Toxic and endocrine disrupting chemicals have been detected in surface water and groundwater near HVHF activity in Pennsylvania. A 2019 study of surface water and groundwater in Susquehanna County, PA, employed a new approach to characterize biological consequences of pollutants in samples and the pollutants that may be responsible (Bamberger *et al.,* 2019). Samples were collected from 33 private wells, 6 streams, 9 ponds, 4 springs, and one lake. Sample proximity to various natural gas infrastructure, including gas wells, compressor stations, and gas dehydrators was determined. Natural gas wells in the county with known casing, cement sheath, and/or other impairments were also identified. The researchers assessed potential toxicity and endocrine activity of the samples with biological assays and determined chemical composition in bulk. The bulk chemical characterizations were then screened for association with anthropogenic activities. One of the biological assays conducted measures aryl hydrocarbon (Ah) receptor activity, which is an indicator of potential immunotoxicity. Other biological assays were conducted to assess endocrine disruption. Ah receptor activity exhibited a strong correlation with proximity to impaired natural gas wells. Endocrine receptor (ER) activities did not show such a correlation. It is not clear whether this lack of ER correlation is due to the absence of endocrine disrupting substances contributed by HVHF activity or simply the fact that other activities, such agriculture, also contributed to the results. ER activity was found to be associated with potential hydraulic fracturing chemicals or wastewater constituents detected in some samples. The study detected 17 potential hydraulic fracturing additives or wastewater constituents that were associated with Ah activity, ER activity, and proximity to impaired wells. The study authors concluded that the association of these chemicals with biological activity and impaired wells suggests that anthropogenic activities, including hydraulic fracturing operations, have resulted in water contamination.

<u>Impacts to surface water from the development of HVHF infrastructure</u>: In addition to the risks described above from HVHF activities involving water, there are risks to water resources from the development of HVHF infrastructure, including construction of roads, well pads, pipelines, and other structures. Construction often involves movement of large volumes of material for slope fill, and erosion of these materials and landslides have been problems. Significant impacts to Pennsylvania streams, especially small tributary streams, by encroachment from slope failures and landslides and by excessive erosion and sedimentation at HVHF well pads have occurred. Some cases were severe and resulted in a PADEP-issued Consent Order and Agreement or a Consent Order and Settlement Agreement in response to these impacts, such as those cases in Aleppo Township, Greene County (PADEP, 2015a), Washington County and Green County (PADEP, 2016d, PADEP 2016e), and Franklin Township, Greene County (PADEP, 2014d). Some details about these cases are described below.

In the 2011 Aleppo Township incident, an operator failed to implement effective erosion and sedimentation control Best Management Practices (BMPs), and a well pad fill slope failed. The resulting landslide, about 250 feet in length, moved about 800 feet downslope and filled about 1,433 linear feet of seven unnamed tributary streams feeding into Harts Run that are designated as warmwater fisheries. Four years later, at the time of the Consent Order and Agreement in 2015, the streams had not been restored (PADEP, 2015a).

In the 2015-16 incidents in Washington County and Greene County, multiple erosion and sedimentation control BMPs were inadequate, not maintained, or not implemented at multiple well pads and an associated soil stockpile and access road. Sediment laden stormwater and soil from the sites moved into unnamed tributaries to Daniels Run and a pond (PADEP, 2016d, PADEP 2016e).

In Greene County in 2012, an operator failed to implement effective erosion and sedimentation control BMPs, resulting in a landslide that developed on a large fill slope at a well pad, causing fill material to encroach into two unnamed tributaries of Grimes Run. Impacts included deforestation of a forested wetland. A contractor for the operator later unlawfully dumped two truckloads (about 200 barrels) of liquid and suspended solid residual wastes over the landslide. The wastes flowed over the landslide material and into a stream, polluting it. The residual wastes were from another well sited owned by the operator (PADEP, 2014d).

Construction activities associated with the unconventional gas development can and have resulted in significant impacts to surface waters and aquatic life.

Risk and Impacts to Aquatic Life

The potential impact to aquatic life from exposure to HVHF fluids and wastewater has been predicted and documented in several reviews (Kahrilas *et al.,* 2014; Stringfellow *et al.,* 2014). Although the toxicity of many chemicals used in HVHF activities is unknown, several studies (many of which were published in 2017 or later) have documented a variety of effects of constituents in HVHF produced waters on biota, including aquatic bacteria, insects, fish, and amphibians. Results of these studies document the extent to which HVHF activities can disrupt, and have disrupted, aquatic organisms, populations, and ecosystems. Toxicological studies provide an indication of the potential for lethal and sublethal effects of substances on aquatic biota. Some laboratory toxicological studies use chemicals or mixtures of chemicals used for HVHF or that are found in flowback or produced waters. Other studies use samples of flowback or produced waters collected at well pads. HVHF chemicals can undergo chemical transformations in the subsurface, and the resulting transformation products can be toxic and impair the treatability and natural attenuation of produced water (Kahrilas *et al.,* 2016). The chemical composition of flowback and produced waters is highly variable both spatially and temporally (U.S. EPA, 2018b), and this variability could be a factor in the outcome of studies that use samples of flowback and/or produced waters from individual wells at specific times following stimulation.

Many studies have assessed aquatic conditions and populations in the field and relate these to proximity to HVHF activities. Results of these types of studies are presented below.

An analysis of the bacterial community profiles in 31 northwestern Pennsylvania headwater stream ecosystems showed that HVHF activity altered the composition of species found in the sediment. Streams near HVHF activity had significantly higher numbers of methane-metabolizing and methane-producing microorganisms, which are tolerant to acidic conditions (Ulrich *et al.,* 2018). As noted previously, microcosm studies showed that biocides used in HVHF can result in aquatic microbial community changes that can affect degradation dynamics and prolong stream impacts.

<u>Laboratory studies of the toxicity of HVHF fluids and wastewater to aquatic life</u>: One relatively early study evaluated the toxicity of HVHF produced water to mayflies. Mayflies are known to be relatively sensitive to changes in water quality and play an important role in the EPT Index that is commonly used to assess water quality by the relative abundance of stream insects that have low tolerance to water pollution (Lenat and Penrose, 1996). Although mayflies represent an important and vulnerable group of organisms inhabiting streams and rivers, they are not generally included in standard toxicity tests of effluents and receiving waters (Sweeney, *et al.* 1993). Mayfly species have been shown to have potential as appropriate species for use in toxicity testing in ambient waters of the Delaware River Basin (MacGillivray, 2013). HVHF produced waters were found to be toxic to mayflies even when diluted by a factor of as much as 100. Produced water entering a small stream, therefore, could cause mayflies to die or otherwise show signs of stress, which could result in measurable changes in stream invertebrates and fish (Stroud Water Research Center, 2013).

Laboratory studies have been conducted on the effects of exposure to diluted HVHF produced water on the survival, reproduction, and behavior of water fleas (*Daphnia magna*). Water fleas are small crustaceans that are an important food source for fish and other aquatic organisms and are sensitive to changes in water chemistry. A 2017 study examined the effects of acute and chronic exposures to produced water on water fleas. Neonate water fleas exhibited a lethal concentration ("LC") value of 50 percent ("LC50") with exposure to 0.19 percent of full-strength produced water, meaning that 50 percent of the neonate fleas died, while adult fleas displayed an LC50 value with exposure to 0.75 percent produced water. A 21-day chronic exposure to 0.04 percent produced water resulted in a decline in water flea reproduction of 71 percent. Results of a 2018 behavioral study also showed that water fleas exposed to HVHF produced water can become immobilized at the water surface and unable to return to the water column. Stranding at the water surface prevents the animals from feeding and impairs their capacity to shed their carapace, impeding reproduction (Blewett *et al.,* 2018). A 2019 study showed that exposure also impaired the ability of water fleas to orient toward light, a response that allows them to avoid predation and find food. These results indicate that exposure to dilute produced waters can induce perturbations in the behavior of aquatic invertebrates, an effect that may influence processes such as feeding and predation rates (Delompré *et al.,* 2019a).

A 2017 laboratory study on sublethal effects of exposure to dilute produced water on zebrafish (*Danio rerio*) showed decreased swim performance and a decrease in active metabolic rate and aerobic scope. Results support the theory that the cardio-respiratory system is impacted by produced water exposure (Folkerts *et al.,* 2017a). Results of a study on the effects of produced water exposure on zebrafish embryos support a hypothesis that organics are major contributors to cardiac and respiratory responses (Folkerts *et al.,* 2017b). A subsequent study examined the effects of isolated organic extracts on zebrafish embryos (He *et al.,* 2018a). Samples were collected from two different gas wells and the organic fractions were isolated from both aqueous and particle phases to eliminate the confounding effects of high salinity. Zebrafish embryos were exposed to various concentrations of produced organic extracts to investigate acute (7-day) and developmental toxicity in early life stages. The acute toxicity lethal dose (LD50) of the extracted produced water fractions ranged from 2.8× to 26× the original organic content of the wastewater. Each extracted wastewater fraction significantly increased spinal malformation, pericardial edema, and delayed hatch in exposed embryos and altered the expression of target genes related to biotransformation, oxidative stress, and endocrine-mediation in developing zebrafish embryos.

Rainbow trout exposed to diluted HVHF produced water showed significant adverse effects, including oxidative stress, endocrine disruption, and biotransformation (He *et al.,* 2016). In a field study of fish exposed to waters of Acorn Creek, Kentucky one month after the upstream release of HVHF fluids (described earlier), exposed fish showed signs of stress and a higher incidence of gill lesions than unexposed reference fish. Gill lesions were consistent with exposure to low pH and toxic concentrations of heavy metals. Gill uptake of aluminum and iron was demonstrated at sites with correspondingly high concentrations of these metals, indicating a persistent impact on aquatic life (Papoulias and Velasco, 2013). Results of other studies of impacts on trout are presented below, in the response to Statement of Concern SC-60.

Some studies have been conducted to determine the toxicity of chemical mixtures representing HVHF fracturing fluids. Studies of the effects of a representative mixture of HVHF chemicals on the immune system of the laboratory frog genus *Xenopus* showed a significant toxic effect. The studies provide strong evidence that at concentrations at or below the levels found in waters near HVHF activity, developmental exposure to a mixture of HVHF chemicals can induce immune system effects in *Xenopus* that persist for a long time after exposure. The results provide unequivocal evidence of long-term negative impacts of short-term exposure to HVHF chemicals on immune function and immune defenses to pathogens. Results of these studies are especially important because, owing to the evolutionary conservation of the immune system across broad classes of organisms, the findings pertain to all jawed vertebrates, including humans (Robert *et al.,* 2019; Robert *et al.,* 2018). A similar study of effects of a mixture of 23 HVHF chemicals on the immune system of mice also found toxic effects and concluded:

> These observations suggest that developmental exposure to complex mixtures of water contaminants, such as those derived from UOG [unconventional oil and gas] operations, could contribute to immune dysregulation and disease later in life.

(Boule *et al.,* 2018). In addition to laboratory studies of toxic effects of HVHF fluids and wastewaters on aquatic life, field studies have documented HVHF impacts to native and introduced aquatic populations. Aquatic trophic structure and mercury biomagnification dynamics were shown to be affected by the presence or absence of unconventional well development in the watersheds of twenty-seven remotely-located streams in the Pennsylvania Marcellus Shale region (Grant *et al.,* 2016). At each stream, stream physiochemical properties, trophic biodiversity, and structure and mercury levels were assessed. Delta 15 N (δ15N), a measure of the stable isotopes in nitrogen; delta 13 C (δ13C) a measure of the stable isotopes in carbon; and methyl mercury in sampled biota were used to determine whether changes in methyl mercury biomagnification were related to the HVHF activities within the streams' watersheds. Results of the study suggest that HVHF activities have the potential to alter aquatic biodiversity and methyl mercury concentrations at the base of food webs.

<u>Field studies of impacts of treated oil and gas wastewater to aquatic life</u>: A USFWS/USGS field study of the effect on freshwater mussels of high-salinity effluent from a plant licensed to treat and discharge conventional oil and gas wastewater (the same area studied by the PADEP in their Aquatic Biology Investigations described earlier) was conducted in the Allegheny River during 2012 (Patnode *et al.,* 2015). Cages containing juvenile northern riffleshell mussels were deployed upstream and downstream of a brine treatment facility, and within the mixing zone of the point of effluent discharge. Mussel survival was severely impaired at and downstream of the facility. Native unionid mussels at upstream, mixing zone, and downstream transects were also surveyed to determine abundance and diversity, which were lower for all transects within the mixing zone and downstream of the facility compared to upstream transects. The results of this study clearly demonstrate in situ toxicity of oil and gas wastewater to juvenile northern riffleshell mussels, a federally endangered species, and to the native unionid mussel assemblage located downstream of the discharge.

Both the Upper Delaware Scenic and Recreational River and the Middle Delaware National Wild and Scenic River are home to populations of dwarf wedgemussel, both a state and federally listed endangered species. The presence and size of dwarf wedgemussel populations (federally endangered) and the presence of the full complement of freshwater mussels is a major contributing element to the ecological Outstandingly Remarkable Value (ORV) and makes the upper Delaware River exemplary at a regional and national scale. As described in a report by the U.S. Fish and Wildlife Service and the Partnership for the Delaware Estuary,

> Based on the limited current distribution of mussels of any species in tributary streams . . . and the patchiness and low mussel abundance within streams

> where they are found, the healthy assemblages that exist in the main stem and tributaries of the Upper Delaware are particularly valuable and require protection. . . . Once extirpated from a stream or reach, mussels are not able to recolonize easily, particularly if there is no longer broodstock nearby. …Most mussels have a long lifespan (30-100 years) and don't reproduce until at least 8 years old. Therefore, even if conditions permit redistribution via fish hosts, recolonization and recovery can take decades. . . . Protection of the existing metapopulation includes ensuring that it does not become further fragmented, less able to disperse and exchange genes, and as a result, less resilient.

(Anderson and Kreeger, 2010).

The research described above demonstrating that HVHF activities have the potential to impact a broad range of aquatic organisms indicates that threatened and endangered aquatic species present within the Basin would potentially be impacted as well. These threatened and endangered aquatic species include the endangered Dwarf wedgemussel (*Alasmidonta heterodon*), Shortnose sturgeon (*Acipenser brevirostrum*), and Atlantic sturgeon (Acipenser oxyrhynchus oxyrhynchus), and the following threatened freshwater mussels: Brook floater (*Alasmidonta varicose*), Green floater (Lasmigona subviridis), and Rayed bean (Villosa fabalis).

In conclusion, results of scientific research provide strong evidence that HVHF activities can result in, and have resulted in, substantial and persistent adverse impacts to surface waters and aquatic life, including threatened and endangered species that are vital to the ecological value of the Basin. The prohibition on HVHF in the Basin is needed to avoid impairing the water uses protected by the Commission's Water Quality Regulations, Water Code and Comprehensive Plan and to conserve water resources and aquatic life.

Statement of Concern (SC-60)

Many commenters expressed concern that spills and illegal dumping of HVHF wastewater, water withdrawals to support HVHF wells, and the associated impacts of these activities on water quality, streamflows, and stream water temperatures could adversely affect trout and other fisheries in the Basin.

Another commenter asserted that there has been no known impact to trout fishing by removing water for gas drilling.

Response (R-60)

Brook trout have already been adversely impacted across much of their native range, primarily because of hydrological, physical, and chemical stresses from anthropogenic land and water alterations (Weltman-Fahs and Taylor, 2013). These alterations have resulted in habitat reduction and fragmentation, water quality and temperature changes, and modification of the biological environment through the introduction of other species (Weltman-Fahs and Walter, 2013). Several studies cite the potential for new, increased or accelerated impacts on trout and other cold water fisheries caused by

HVHF activities resulting in pollution, water withdrawals, and landscape alterations that in turn affect water quality, water temperature, and instream flows.

The Pennsylvania Department of Conservation and Natural Resources (DCNR) has reported that stressors on brook trout from unconventional gas development include contaminated fluid spills, improper erosion and sedimentation control, habitat fragmentation, increased impervious surface area, stream crossings, water withdrawals, and ground water contamination (PA DCNR, 2016). Laboratory tests of the short-term toxicity of HVHF produced waters on rainbow trout indicate significant adverse effects, including oxidative stress, endocrine disruption, and biotransformation. Organic compounds might play a major role in toxicity (He *et al.,* 2016). A 2019 study of 28-day exposure to dilute (3 percent) flowback and produced water (collected from a single gas well by the well operator) did not find toxicity or ionoregulatory effects in trout (Delompré *et al.,* 2019b). However, as noted previously, the chemical composition of produced waters is highly variable both spatially and temporally (U.S. EPA, 2018b), and this variability could be a factor in the outcome of studies that use flowback and/or produced waters collected from individual wells at specific times following stimulation.

A 2017 study of fish assemblages, brook trout abundance, and stream pH in streams with and without nearby hydraulic fracturing activity suggest that hydraulic fracturing in Pennsylvania has the potential to affect stream pH, fish assemblages, and wild brook trout abundance (Grant *et al.,* 2017). A 2019 study of a cluster of first-order headwater streams in Pennsylvania found evidence of a direct link between brook trout health, macroinvertebrate distribution, and HVHF activity (Weltman-Fahs, 2019).

Many aquatic species including fish develop a protective mucus on the epidermis that acts as a first line of defense against a wide array of environmental contaminants, pathogens, parasites, and predators. The mucus can also aid in buoyancy, swimming, communication and feeding. Bacteria inhabit this protective microenvironment and can provide further protections to the fish against opportunistic bacterial pathogens. A 2018 study assessed the effects of hydraulic fracturing waste on the epidermal bacterial community of brook trout (Salvelinus fontinalis). Results of the study suggest that exposure to low levels of hydraulic fracturing waste influences bacterial colonization and may lead to a disruption that favors bacterial populations associated with fish disease (Galbraith *et al.,* 2018).

A large-scale assessment of HVHF activity on brook trout was conducted in the Upper Susquehanna River Watershed BY West Virginia University, Loyola University, Susquehanna University, and the U.S. Geological Survey (Merriam *et al.,* 2018). A statistical analysis—a boosted regression tree (BRT) analysis with a predictive capability rated as 'excellent'--was used to predict the occurrence probability of brook trout as a function of natural and anthropogenic landscape and climate factors, including HVHF activity, in over 25,000 stream segments. The model was also used to predict the response of brook trout occurrence probability to the buildout of 934 undeveloped of unconventional natural gas permits. The relative influence of HVHF activity in the model was small (0.7 percent); the dominant predictors accounting for most of the relative influence were seven natural features (total of 72 percent); and non-HVHF anthropogenic features (agriculture—20.9 percent; Developed land—5.6 percent). Results showed that HVHF activity impacted 11 percent (n=2784) of stream segments and resulted in the loss of predicted brook trout occurrence in 126 of these stream segments. Simulated development of permitted but undeveloped wells resulted in a loss of predicted brook trout occurrence in 27 additional stream segments. The occurrence losses occurred in streams that also were characterized by non-HVHF stress and/or natural habitat quality that were close to critical threshold values. This result indicates that even in circumstances where HVHF activities are only a relatively small contributor to the stress on brook trout, they may play a critical role in causing impairment when combined with non-HVHF stressors.

The above-described studies and report indicate that HVHF activities have the potential to adversely affect, and have adversely affected trout health. The proposed regulations are intended to prevent such impacts as a result of HVHF activities in the Delaware River Basin.

Statement of Concern (SC-61)

Portions of the DRB are sanctuary to rare and endemic species of plants and animals and home to the highest concentration of rare, threatened, and endangered species in Pennsylvania. Many of these plants and animals are extremely vulnerable to changes in habitat, stream flows, water chemistry, temperature, and turbidity that could result from the varied effects of unconventional natural gas development. Changes to stream water quality have been shown to occur where gas drilling and related activities are located.

Response (R-61)

The Commission acknowledges that HVHF activities could alter aquatic habitat characteristics, including among others, in-stream flow and water quality. A 2015 study was conducted to determine the sensitivity of HUC12 catchments to negative effects due to HVHF-related surface disturbance or water use. Results indicate that the DRB portion of the Marcellus region is predicted to be generally less sensitive to this type of stressor exposure than HUC12 catchments in other shale-gas regions across the nation (Entrekin *et al.,* 2015, Fig. 3). However, impacts to surface water and aquatic life from HVHF activities in the Marcellus region have already been documented, as described above and elsewhere in this document. The regulations are intended to prevent any adverse impacts to water resources and aquatic habitats in the Delaware River Basin by activities associated with high volume hydraulic fracturing.

Statement of Concern (SC-62)

DRBC should continue its efforts to develop ecological flows to protect aquatic resources.

Response (R-62)

DRBC intends to continue its review of ecological flows in Basin waterways to assure sufficient flow is provided under varying hydrologic conditions and a variety of temporal and spatial water demands.

Statement of Concern (SC-63)

Inadequate regulation of stormwater from well sites, leading to polluted runoff, erosion and sedimentation from these sites causes adverse impacts to water quality, the rate and volume of water flow, stream morphology, riparian buffers and vegetation, the loss of groundwater infiltration and recharge of aquifers, and the reduction of healthy base flow of streams.

RESPONSE (R-63)

The Commission acknowledges the various potential impacts of stormwater runoff from well sites. Within the Pennsylvania portion of the Basin, stormwater runoff, including runoff related to hydraulic fracturing activities if undertaken, would currently be regulated by the Pennsylvania Department of Environmental Protection (PADEP), implementing the National Pollutant Discharge Elimination System (NPDES) permit program under the federal Clean Water Act and the Pennsylvania Clean Streams Law. The Erosion and Sediment Pollution Control Program Manual developed by the Pennsylvania Department of Environmental Protection informs those engaged in earth disturbance activities of the elements of an Erosion and Sediment Control (E&S) Plan required to comply with state regulations found at 25 Pa. Code Chapter 102 (PADEP, 2012). Although DRBC imposes stormwater management requirements through its regulations protecting Special Protection Waters and its rules requiring the development and implementation of pollutant minimization plans for PCBs, the Commission has not developed detailed regulations for the management of stormwater. The regulations are intended to prevent adverse impacts to water resources and aquatic habitats in the Delaware River Basin by activities associated with high volume hydraulic fracturing.

IMPACTS TO SURFACE WATERS AND AQUATIC LIFE - SUMMARY

The Commission's responses to the numerous comments it received on potential impacts to surface water and aquatic life, based on the staff's careful evaluation of a decade of scientific data and literature on this subject, are summarized below:

- Risks to surface waters and aquatic life from high volume hydraulic fracturing and related activities include releases of chemicals and highly contaminated fluids from spills and accidents, failure of well integrity, inadequate wastewater treatment, improper wastewater disposal, transport and discharge of pollutants with stormwater, and stream depletion from water acquisition.

- A large body of compelling scientific research has shown that high volume hydraulic fracturing and related activities can result in, and have resulted in, substantial and persistent adverse impacts to surface waters and aquatic life.

- Results of extensive studies of centralized wastewater treatment facilities that treated HVHF wastewater in the past demonstrate that even treated wastewater from HVHF activities can adversely impact and has adversely impacted surface waters and aquatic life. As a result of these impacts, the PADEP in 2011 asked operators to stop discharging shale produced water to wastewater treatment plants that were exempt from the 2010 TDS regulation.

- Effluent from CWT facilities treating HVHF wastewater can result in and has resulted in persistent sediment contamination many miles downstream of the discharge location.

- Impacts of effluent from CWT facilities treating HVHF wastewater on river sediments and biota can be persistent, and even discharges of short duration may leave a long legacy.

- As the number of producing HVHF wells increases, the demand for CWT services to treat and discharge HVHF wastewater to streams will likely increase. If HVHF were allowed in the Basin, demand for new CWT services in the Basin to treat the wastewater generated by HVHF in the Basin would likely arise.

- The adverse effects of the discharge of treated HVHF produced water on water resources at locations outside the Delaware River Basin support the conclusion that planned and/or accidental discharges of untreated HVHF produced water with high concentrations of pollutants would likewise harm water resources within the Delaware River Basin.

- Activities at a deep well disposal facility used to dispose HVHF wastewater impacted a nearby stream and altered the biogeochemistry of nearby ecosystems.

- Numerous spill and construction incidents that occurred during various stages of HVHF activities have resulted in adverse impacts to surface water and/or aquatic life.

- Model analysis of the effects of water acquisition for HVHF activities on stream flows and water quality showed that potential effects are slight, and that SRBC's regulations were effective in reducing HVHF impacts on streamflow in the SRB.

- Results of SRBC's 2016 and 2019 monitoring reports have been largely misreported as demonstrating no impact on surface water quality as a result of hydraulic fracturing. SRBC itself and other authoritative sources, including the U.S. Geological Survey, have described the results of SRBC's reports as inconclusive with respect to any hydraulic fracturing impacts.

- Although the toxicity of many chemicals used in HVHF activities is unknown, several studies (many of which were published in 2017 or later) have documented a variety of adverse effects on biota, including aquatic bacteria, insects, fish, and amphibians, of constituents in HVHF produced waters.

- HVHF produced waters were found to be toxic to mayflies even when diluted by a factor of as much as 100.

- Exposure to dilute flowback and produced waters can induce perturbations in the behavior of aquatic invertebrates, an effect that may influence vital processes such as feeding and predation rates and reproduction.

- Highly dilute HVHF production water caused significant adverse effects, including oxidative stress, endocrine disruption, and biotransformation in trout and equally serious effects on other fish species.

- Developmental exposure to complex mixtures of water contaminants, such as those derived from unconventional oil and gas operations, could contribute to immune dysregulation and disease later in life – for frogs, mice and other animals, including humans.

- HVHF activities have the potential to alter aquatic biodiversity and methyl mercury concentrations at the base of food webs.

- The Commission agrees with and relies on the EPA's understanding and interpretation of the peer-reviewed scientific research published through 2016; the EPA's conclusions that hydraulic fracturing activities can impact water resources under some circumstances; and EPA's finding that these impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors.

- After EPA issued its final report on Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States in 2016, additional published scientific research has reinforced EPA's conclusions and provided additional compelling evidence that HVHF may be accompanied by adverse impacts on water resources.

The Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, primarily: in rural areas dependent upon groundwater resources, in sensitive headwater areas considered to have high water resource values, in areas draining to DRBC Special Protection Waters, and in a region characterized by extensive geologic faults and fractures that could become pathways for migration. Adverse impacts to surface waters and aquatic life would inevitably occur, as the result of planned or accidental discharges of harmful pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined.

A decade of experience in other regions has shown that regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills, and releases of chemicals and hydraulic fracturing wastewater. Accordingly, the Commission has determined that controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.3.3 Groundwater

Groundwater resources include present and future subsurface sources of drinking water that are withdrawn through supply wells and also groundwater that flows into surface water and supports streamflows, lakes, wetlands, and their associated aquatic habitats. Prior Section 2.3.3.1 responds to comments on impacts to drinking water resources. This section responds to comments on the broader issue of impacts to groundwater. Many commenters expressed views about impacts of high volume hydraulic fracturing activities on groundwater. Some expressed concern that hydraulic fracturing and related activities would result in pollution of groundwater resources or excessive drawdown of aquifers. Other commenters maintained that hydraulic fracturing can and has been performed safely, and that concerns about potential impacts to groundwater are overblown.

STATEMENT OF CONCERN (SC-64)

Representative examples of comments generally supporting Section 440.3 of the rule and opposing hydraulic fracturing in the Delaware River Basin are paraphrased below:

- Sections 2.20.2 and 2.20.3 of the Water Code authorize and require the DRBC to preserve and protect underground water-bearing formations, and to safeguard the public interest from projects that withdraw underground waters.
- Contamination of groundwater aquifers by hydraulic fracturing occurs underground and involves at least three different substances – natural gas, formation brine, and hydraulic fracturing fluid. The contaminants can follow natural fractures and faults in the subsurface rock formations or can travel from a poorly constructed gas well and/or through abandoned wells.
- Formation brine naturally flows through faults and fractures from the Marcellus or other deep Appalachian basins to shallow groundwater based on geochemical and isotopic evidence. These connections could allow more rapid brine flow or portend the flow of hydraulic fracturing fluid to shallow groundwater due to increased pressure or enhanced connections due to hydraulic fracturing (Llewellyn, 2014; Warner *et al.,* 2012b).
- Hydraulic fracturing pollutes groundwater, destroying the quality of aquifers for generations to come. The chemicals in hydraulic fracturing fluids will migrate to drinking water aquifers and to the surface – it is not a question of "if," but "when."

Representative comments opposing Section 440.3 of the rule and supporting hydraulic fracturing in the Delaware River Basin are paraphrased below:

- DRBC's proposal to prohibit HVHF operations in the Delaware River Basin is an extreme overreaction based upon either a misunderstanding or a misinterpretation of the most current and accurate information about the level of risk to surface water and groundwater sources from HVHF operations.
- The science and data clearly demonstrate that hydraulic fracturing can be and has been done safely and responsibly.
- The potential risks to the environment posed by unconventional gas development are controllable and negligible and are offset by considerable potential benefits.
- Our nation's public policies – at all levels of government – must be based on evidence, science, and necessity. A vocal minority of activists should not be able to block nationally vital energy development because of their own false fears. The evidence is clear that hydraulic fracturing is safe and effective.

RESPONSE (R-64)

DRBC aims through development and implementation of policies and practices informed by science to fulfill its responsibilities under the Delaware River Basin Compact for management of the Basin's water resources – both above and below the ground. The Commission appreciates the support expressed by many commenters for the regulations as an appropriate way to meet this responsibility. Although we also recognize and appreciate industry's efforts to develop unconventional gas resources safely, based on the evidence set forth below, we disagree that the regulations are an over-reaction. To the contrary, the most current and reliable information available highlights the serious risks, vulnerabilities and impacts to water resources posed by high volume hydraulic fracturing.

The Commission's regulations, plans and policies have been developed and implemented over the course of nearly six decades to underpin and implement a comprehensive water resource management program or "Comprehensive Plan." *See* Compact §§ 3.2(a) and 13.1. The Commission's Comprehensive Plan and Water Code constituting part of the Comprehensive Plan provide, "The underground water-bearing formations of the Basin, their waters, storage capacity, recharge areas, and ability to convey water shall be preserved and protected." (Water Code § 2.20.2). These instruments further provide, "Projects that withdraw underground waters shall be planned and operated in such manner as will reasonably safeguard the present and future public interest in the affected water resources" (Water Code § 2.20.3) and that the quality of the Basin's groundwater shall be maintained in a safe and satisfactory condition for uses that include public water supplies, except where such uses are precluded by natural quality.

Although the long-term impacts of the shale gas industry on groundwater are not yet fully understood, the scientific evidence to date, as set forth in detail below and in other sections in this document, makes clear that in those regions outside the Basin where high volume hydraulic fracturing has been intensively used to extract oil and gas from shale, this practice and the activities that accompany it have resulted in adverse impacts to groundwater that, were they to occur within the Basin, would substantially impair the effectuation of the Commission's Comprehensive Plan.

The potential for HVHF to adversely impact the quality of groundwater resources in the Basin due to the migration of gas and/or fluids is a technically complex topic and the subject of many investigations and research activities. Numerous scientific papers and reports document evidence of the presence of gas and/or suspected hydraulic fracturing fluids or produced water in groundwater in different settings and circumstances. Other studies find no or little evidence of migration of gas or fluids in other settings. Comprehensive and authoritative reports that synthesize much of this information include the U.S. Environmental Protection Agency's ("EPA") 2016 final report on impacts from the hydraulic fracturing water cycle on drinking water resources in the United States (U.S. EPA, 2016a), and the New York State Department of Environmental Conservation's ("NYSDEC") 2015 Final Supplemental Generic Environmental Impact Statement on [New York's] Oil, Gas and Solution Mining Regulatory Program (NYSDEC, 2015a). The former found that hydraulic fracturing activities can impact water resources under some circumstances, and that these impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors (U.S. EPA, 2016a, p. ES-3). The latter found that the adverse environmental impacts that could result from high volume hydraulic fracturing may have adverse public health outcomes, including drinking water impacts from underground migration of methane and/or fracturing fluid chemicals associated with faulty well construction or seismic activity (NYSDEC, 2015b, p.25). The Commission agrees with and relies on these conclusions and finds that they are reinforced by additional peer-reviewed research published since the EPA and NYSDEC reports were issued.

The Commission agrees with the view that gas, hydraulic fracturing fluids, and formation brine can migrate to the surface through natural geologic faults and fractures, or through abandoned wells or poorly constructed natural gas wells, or via a combination of both. The Commission notes that there are likely few abandoned wells in the Delaware River Basin at present, and the PADEP adopted regulations in 2016 to address communication with offset wells, including abandoned wells. Based on the published literature to date, the Commission finds that gas and other fluids are more likely to migrate through poorly constructed or abandoned gas wells than solely through natural faults and fractures, and gas is more likely than liquid to migrate in this manner and to adversely affect groundwater resources. Faulty well integrity has plagued the oil and gas industry for decades and is especially problematic for HVHF wells, as discussed in detail in Section 2.3.2.3 (Pollution from Fluid Migration). Pennsylvania upgraded its casing and cementing/well construction and operation regulations in 2011 to include provisions establishing well integrity review, remediation and reporting requirements (*see* Appendix-4). DRBC further finds that the probability of fluid migration is low in "typical" unglaciated, tectonically tranquil shale-gas settings where the target formation is deep, flat-lying, and characterized by low permeability, and in which gas wells are constructed and maintained properly. However, the weight of the evidence in the Commission's view also shows that the probability of fluid migration as a result of HVHF activity may be substantially higher in other settings, including in northeastern Pennsylvania, where numerous documented incidents of impacts on groundwater have occurred in connection with natural gas extraction. These incidents have occurred where wells have not been constructed or maintained properly or where the geologic characteristics present in this region contribute to elevated risk (or both). In northeastern Pennsylvania and in the New York part of the Basin the rock formations have been extensively folded, faulted, and eroded through geologic time. As a result, the Marcellus Shale dips upward rapidly and crops out at the earth's surface in places near the Delaware River. A consequence of this structural change and the associated low-grade metamorphism is the presence of rock cleavage, a greater tendency for fracturing and higher permeability, and therefore greater risk for fluid transport to adjacent formations. Several studies have been conducted using different approaches and in different areas to determine the presence or absence of geologic features with relatively high permeability that could potentially provide pathways for subsurface migration of HVHF fluids (including gas) to shallow groundwater. Results of many studies of the Marcellus region in northeastern Pennsylvania and New York suggest the possible presence of such features. The technical rationale and references for these conclusions are presented in Section 2.3.2.3, Pollution from Fluid Migration.

The activities and materials associated with high volume hydraulic fracturing for the extraction of oil and gas from shale pose a unique set of risks to water resources. These activities and materials can result, and in documented instances have resulted, in significant impacts to groundwater resources. Moreover, the long-term impacts on groundwater resources of this relatively young phase of the industry are not fully understood and may not be fully understood for decades, as indicated by a study by the U.S. Geological Survey (McMahon *et al.,* 2017). Known risks to groundwater in connection with HVHF activities, and scientific studies that highlight present knowledge of local and regional HVHF impacts to groundwater are presented below.

Risks to Groundwater

Assessing the potential for HVHF impacts to groundwater requires an understanding of all phases of HVHF and supporting activities and an understanding of the hydrologic linkage between surface water and groundwater. The EPA's 2016 report describes in detail the five stages of the "hydraulic fracturing water cycle," consisting of: water acquisition, chemical mixing, well injection, produced water handling, and wastewater disposal and reuse (U.S. EPA, 2016a, p. ES-9). The section of the report on well injection includes a discussion of well construction, including the importance of mechanical integrity, and the implications of the loss of mechanical integrity as wells age.

As noted previously in the section on surface water impacts, the interaction between surface water and ground water is an important process that factors into the risks of HVHF activities to groundwater and surface water and is considered in studies of HVHF impacts. The interaction takes place two ways in the Basin; in most areas and under most conditions, streams gain water from the inflow of groundwater through the streambed; in other areas and/or under other conditions, streams lose flow to groundwater. Some streams do both, gaining flow in some reaches, and losing flow in other reaches. Streams can also gain flow under some conditions (such as low-flow conditions) and lose flow under other conditions (such as during flood events). As water flows between groundwater and surface water, contaminants can move with it. Contaminants in groundwater can be transported into adjacent surface water, and contaminants in surface water can be transported into adjacent groundwater. While surface water transport of contaminants is relatively rapid, the transport of contaminants through groundwater is usually very slow.

Risks to water resources at each stage of the hydraulic fracturing water cycle were identified by the EPA, and risks specific to groundwater are noted in Table 9, adapted from the EPA report:

Stage of Hydraulic Fracturing	Risks to Groundwater	Potential Contaminant Transport Pathways
Water acquisition	• Excessive aquifer drawdown	N/A
Chemical mixing	• Spills, leaks, and other releases	• infiltration and subsurface migration • Combinations of surface flow and subsurface flow
Well injection (includes activities associated with well construction, stimulation, production, and post-production)	• Migration of drilling fluids during construction • Migration of gas and/or fluids from target formation to aquifers or streams • Migration of gas from non-target formations to aquifers or streams • Spills, leaks, other releases of fluids (Blowouts, other equipment failures, transport failures, interwell-bore communications)	• Subsurface flow • Combinations of surface flow and subsurface flow
Produced water handling	• Spills, leaks, and other releases	• infiltration and subsurface migration • Combinations of surface flow and subsurface flow
Wastewater disposal and reuse	• Improper storage, treatment, or disposal • Reuse for roadway de-icing or dust control	• Infiltration and subsurface migration

Table 9: Risks to Groundwater at Each Stage of the Hydraulic Fracturing Water Cycle

The risks noted in the table are described in greater detail below, as are potential and documented impacts to groundwater that have been described in the scientific literature and agency reports.

WATER ACQUISITION – Each HVHF event utilizes millions of gallons of freshwater, and the majority of water used is permanently removed from the hydrologic cycle. Based upon a review of data for activity in Pennsylvania, the Commission agrees that the volume of freshwater used in each hydraulic fracturing event is increasing (Kondash *et al.,* 2018). In Pennsylvania, the average amount of water used per event has increased from 7.46 million gallons to 16.04 million gallons as documented in an analysis of FracFocus Data for 2013-17 by ALL Consulting, LLC (ALL Consulting, 2018). In the Susquehanna River Basin of Pennsylvania during 2008-2013, about 16 percent of injected water came from reused HVHF wastewater (U.S. EPA, 2016a, p. 4-7). The EPA conducted a study of the impacts of HVHF water acquisition on water availability (U.S. EPA, 2015a). The study included a detailed analysis of these impacts from development of the Marcellus Shale in the Susquehanna River Basin. Based on groundwater flow modeling of the 215-square-mile Towanda Creek Watershed, annual aquifer recharge was equivalent to between three and six percent of the volume of freshwater in the groundwater reservoir. The annual withdrawals for all uses, including HVHF activities) was estimated to equal between 1.1 and 1.7 percent of annual recharge. From this result, the study concluded that the potential for hydraulic fracturing impact on groundwater availability at the watershed scale of 215 square miles appears to be small. The study also examined the potential for local impact due to well drawdown at a representative public water supply in Bradford County and a private wellfield in Wyoming County. The study found no observed or reported local impacts from hydraulic fracturing water acquisition. Other conclusions of the study are described in Section 2.3.3.2 Surface Waters and Aquatic Life of this document. Responses to other comments regarding water use for hydraulic fracturing are presented in Section 2.3.3.1 Water Use.

CHEMICAL MIXING – The chemical mixing stage includes the mixing of base fluid, proppant, and additives on the well pad to produce the fluid used for hydraulic fracturing. This fluid is engineered to create and extend fractures in the targeted formation and to carry proppant into the fractures. Concentrated additives, often including biocides, are delivered to the well pad and stored on site, often in multiple, closed containers, and moved around the well pad in hoses and tubing (U.S. EPA, 2016a, p. ES-22). Many chemicals from hydraulic fracturing activity are known to be hazardous, meaning that they are carcinogenic, endocrine disrupting, produce adverse immune or nervous system effects, and/or are toxic to reproductive and developmental systems. However, not all of the chemicals and additives used in hydraulic fracturing have been identified, and toxicity values have been established for only a subset of the identified substances (U.S. EPA, 2016a, p. ES-43). Depending on the concentrations and synergistic effects of chemicals during exposure, based on the known properties of substances used and generated by hydraulic fracturing, their potential human health effects include toxicity to multiple human organs, sensitization, irritation, developmental effects, and tumor promotion (Kassotis *et al.,* 2018).

Another potential risk associated with some HVHF chemicals is the potential for relatively rapid migration in groundwater as a consequence of low rates of sorption to soils. Sorption is often the most important process controlling the subsurface behavior of contaminants, and contaminants with low sorption can be transported rapidly. Factors influencing sorption include water solubility, polar/ionic character, octanol/water partition coefficient, acid/base chemistry, and oxidation/reduction chemistry (Piwoni and Keeley, 1990). Samples of HVHF wastewater from the Duvernay

Formation in Alberta, Canada, were found to contain a previously unidentified class of aryl phosphates, including diphenyl phosphate (DPP), triphenyl phosphate (TPP), and others. The sorption of DPP onto both clay-rich soils and sandy sediment was measured and found to be low compared to that of other aryl phosphates. If released to the surface or subsurface, the transport of DPP to groundwater would be rapid due to its low degree of sorption on surficial materials. (Low sorption is one of the reasons why the compound MTBE was phased out as a fuel additive in the United States.) Toxicological studies by the Canadian research team and others showed toxic effects on zebrafish embryos and chicken embryo tissue from low-level exposures to DPP. The researchers inferred from these results that DPP may pose an environmental risk to aquatic ecosystems if released into the environment (Funk *et al.,* 2019). Many hydraulic fracturing chemicals share this type of risk as a result of low sorption. According to the EPA:

> . . . many chemicals [used in hydraulic fracturing] have high solubilities and negative or almost zero log K_{OW} [octanol/water partition coefficients] (e.g. methanol, isopropanol, ethylene glycol). These chemicals are likely to travel quickly through the environment and could result in an immediate impact.

(U.S. EPA, 2016a, p. 5-56). Risks to groundwater during the chemical mixing stage include spills, leaks, explosions and other fluid releases that can result in the infiltration of contaminants and subsurface transport to aquifers. The Commission acknowledges that the industry has developed measures that, if implemented properly, can reduce the potential for fluid releases. These measures include zero-discharge and controlled-collection well pad containments. Despite their deployment, however, impacts on groundwater or surface water due to overflows, liner breaches, tank corrosion and leakage, casing, hose, or pipeline ruptures, fires, and other construction and equipment issues have been documented (*see, e.g.,* Frazier, 2017a; PADEP, 2017c; PADEP, 2016b; PADEP, 2016c; PADEP, 2016d; U.S. EPA, 2016a, p. 8-43; PADEP, 2014b; PADEP, 2014c; U.S. EPA, 2014; Williamsport Sun-Gazette, 2014; Considine *et al.,* 2012; Detrow, 2012; MDN, 2012; Gilliland, 2011; Legere, 2011). Despite improved construction standards, impacts to groundwater or surface water continue to occur due to overflows, liner breaches, and construction issues. Some examples of spill incidents that resulted in impacts to groundwater are presented below. Responses to additional comments about chemicals used in hydraulic fracturing and spills are presented in Section, 2.3.2.2, Pollution from Spills.

WELL INJECTION – The well injection stage involves the injection of hydraulic fracturing fluids through the production well and their movement in the production zone. This stage also includes activities at the well site before and after injection, including well construction, production, and post-production. During the process of well injection, the fluid mixtures described above are pumped into the well at high pressure. The pressure is increased until it exceeds the formation strength and fractures the rock. Improper well construction or equipment failure during fracturing operations can result in the release and/or migration of HVHF fluids, gas, and formation waters.

The subsurface migration of gas and/or fluids requires a pathway, induced or natural, with high enough permeability and a hydraulic gradient to drive the movement at relevant rates. EPA describes the categories of potential subsurface migration pathways of HVHF gas, fluids, and formation waters as follows:

- Migration out of the production zone through pore space in the rock;

- Migration due to fracture overgrowth out of the production zone;
- Migration via fractures intersecting offset wells or other artificial structures; and
- Migration via fractures intersecting other geologic features, such as permeable faults or pre-existing natural fractures (U.S. EPA, 2016a, p.6-44).

Migration through these four potential pathways may act in combination with each other and/or in combination with migration through pathways along the wellbore to affect groundwater. Some examples where the release of fluids or gas during well injection or during other HVHF-related activities resulted in impacts to groundwater are presented below. Technical details about these examples and fluid migration in general are provided in Section 2.3.2.3, Pollution from Fluid Migration.

PRODUCED WATER HANDLING – Produced water is a waste generated during shale gas production that flows to the surface through the production well along with gas. Operators must store, treat, and/or dispose of large amounts of produced water, either on site or off site. Produced water from hydraulic fracturing activities has been found to contain:

- Salts, including those composed from chloride, bromide, sulfate, sodium, magnesium, and calcium;
- Metals, including barium, manganese, iron, and strontium;
- Naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes (collectively, "BTEX"), and oil and grease;
- Radioactive materials, including radium; and
- Hydraulic fracturing chemicals and their chemical transformation products (U.S. EPA, 2016a, p.7-1).

Risks to groundwater during produced water handling include spills, leaks, explosions and other fluid releases that can result in the infiltration of contaminants and subsurface transport to aquifers. Responses to comments on spills during produced water handling are presented in Section 2.3.2.2, Pollution from Spills.

WASTEWATER DISPOSAL AND REUSE – This final stage of the hydraulic fracturing water cycle consists of the management of wastewater, including disposal, recycling and reuse in hydraulic fracturing operations, and other reuses. Until 2011, much of the produced water generated by HVHF in Pennsylvania was treated inadequately at publicly owner treatment works ("POTWs") and discharged to surface water (U.S. EPA, 2016a, pp. 8-19 – 8-20). Following the discontinuation of this practice, other means of disposing of HVHF wastewater were needed. Currently, most of the HVHF wastewater produced in Pennsylvania is either reused to hydraulically fracture other wells or is transported for disposal through deep well injection, primarily in Ohio and West Virginia, but also within Pennsylvania.

The spreading of oil and gas wastewaters on roadways for deicing or dust suppression is another means by which HVHF activity could impact groundwater resources. From July 2009 to June 2010, about 13,000 gallons of Marcellus Shale hydraulic fracturing wastewater was reportedly spread on roads in Pennsylvania (Rozell and Reaven, 2011). Road spreading of brine from unconventional wells is explicitly forbidden by Pennsylvania's regulations. *See*, 25 Pa.Code §§ 78a.70 and 78a.70a. A 2018 study led by Penn State University found that oil and gas wastewaters spread on roads in the north-eastern U.S. have salt, radioactivity, and organic contaminant concentrations often many times above drinking water standards (Tasker *et al.,* 2018). The study also found that in Pennsylvania from 2008 to 2014, spreading oil and gas wastewater on roads released over 4 times more radium to the environment (320 millicuries) than oil and gas wastewater treatment discharges and 200 times more radium than spill events. Lab experiments demonstrated that nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water. Additional detail about roadway spreading is presented in Section 2.7.7 (Application of Hydraulic Fracturing Produced Water/Wastewater).

Documenting Impacts to Groundwater

Documenting the occurrence of groundwater pollution from HVHF activities can be challenging, as many factors and complexities can come into play. Attributing groundwater pollution to a particular source and contaminant transport pathway with dispositive evidence can be especially difficult. The process of attribution may involve some combination of investigative procedures, including potential source evaluation, environmental sampling, complex laboratory analyses (sometimes involving isotopic and noble gas analyses), chemical fingerprinting, analysis of event chronologies, detailed assessment of well construction, geologic and hydrogeologic analysis and interpretation, time series analyses, geospatial analyses, and consideration of alternative hypotheses. A phased approach for conducting this type of evaluation in the future was proposed by an international academic team (McIntosh *et al.,* 2019). Advanced analytical techniques for source detection using matrix factorization are also being explored (Zheng *et al.,* 2019). In the meantime, the scientific method has provided the critical framework and process for collecting and utilizing information to answer questions methodically and rationally and build scientific consensus in the face of uncertainty. In many cases, the information available for source or pathway attribution is indirect but may strongly indicate (or rule out) a source or migration pathway. In evaluating the information available to them, scientists consider the weight of evidence, and conclusions are often expressed in qualitative, probabilistic terms to convey the level of certainty. Conclusions often use gradations of descriptors such as "likely," "highly likely," "unlikely," "highly unlikely," "possibly," "plausibly," etc. In evaluating conclusions and aggregate meaning of many (sometimes conflicting) environmental investigations relating to HVHF, the Commission likewise considered the weight of the evidence, as well as the reasoning and conclusions of the comprehensive HVHF assessments conducted by EPA (U.S. EPA, 2016a) and the State of New York (NYSDEC, 2015a).

Local impacts to groundwater quality

Impacts to groundwater quality are investigated at different scales. At the local scale, an individual instance or a cluster of instances of HVHF impact in a relatively small area may be intensively investigated to determine a likely explanation for the impact. At the regional scale, a larger area is considered, often with the intent of determining if HVHF impacts are widespread, systematic, patterned, related to landscape or geologic factors, and/or predictable. Examples of local HVHF impacts to groundwater quality are described below. Examples of regional impact studies follow.

Groundwater contamination resulting from the migration of HVHF chemicals: Local studies have demonstrated that HVHF activities can result in, and have resulted in, the migration of HVHF chemicals to groundwater. The blowout spill near Killdeer, North Dakota is an early example of a major accident that impacted groundwater resources. During hydraulic fracturing operations in the Bakken formation in 2010 near Killdeer, North Dakota, the production, surface, and conductor casing of the Franchuk 44-20 SWH well ruptured. Despite a shutdown of the pumps, the pressure was sufficient to cause fluid to move through the ruptured casings and flow to the surface. As a result of the blowout spill, over 166,000 gal (628,000 L) of fluids and approximately 2,860 tons (2,595 metric tons) of soil were contaminated and needed to be removed from the site. Subsequent groundwater monitoring of observation wells constructed near the production well identified brine contamination in the Killdeer Aquifer. The composition of the brine contamination was consistent with mixing of Killdeer Aquifer groundwater with brine from Madison Group formations, which the production well had penetrated. Ion and isotope ratios used for brine fingerprinting suggest that Madison Group formations (which directly overlie the Bakken in the Williston Basin) were the source of the brine observed in the Killdeer Aquifer. The authors concluded that these results provide evidence for out-of-zone fracturing, which is a common problem in Bakken formation wells. The groundwater monitoring also indicated the presence of tert-butyl alcohol ("TBA"), consistent with degradation of tert-butyl hydroperoxide, a component of the hydraulic fracturing fluid used in the Franchuk well. Based on the analysis of potential sources of contamination, the EPA determined that the only potential sources of TBA were gasoline spills, leaky underground storage tanks, and hydraulic fracturing fluids. The lack of MTBE and other signature compounds associated with gasoline or fuels strongly suggested that the rupture (blowout) was the only source consistent with findings of high brine and TBA concentrations in the two wells (U.S. EPA, 2016a, p.6-21; U.S. EPA 2015c., p. 3) The incident and results of this study provide compelling evidence that the migration of HVHF fluids initiated during the well injection stage can impact, and have impacted, groundwater resources.

In the area around the Pavillion gas field in Wyoming, a study by Stanford University found that organic contaminants reached domestic wells due to subsurface migration of the contaminants from unlined pits used to dispose diesel-fuel based drilling mud and production fluids (DiGiulio and Jackson, 2016).

Ten gas wells on five pads in Bradford County, PA were constructed between 2009 and 2010, between approximately one and 2.25 kilometers (0.6 to 1.4 miles) north of a small valley along the north branch tributary of Sugar Run in Bradford County, where several private homes used groundwater for their drinking water. About two months after HVHF activity commenced, some of the previously potable water supplies became contaminated by gas, a foaming agent, and chemical signatures similar to those of flowback from hydraulic fracturing in the Marcellus Shale in other areas. An investigation of the source of the contamination of the residential wells used multiple lines of evidence, including: (1) time series analyses of natural gas and organic and inorganic compound concentrations; (2) comparisons of natural gas isotopic compositions between gas well annular gas and groundwater; (3) assessments of gas well construction; (4) chronology of events; (5) hydrogeologic characterization; and (6) geospatial relationships. The study used a coupled gas chromatography/mass spectrometry analytical method that identified similar unresolved complex mixtures of organic compounds in the affected aquifer and in flowback from other Marcellus Shale gas wells.

Using results from these six lines of evidence, the researchers concluded that stray gas and drilling or hydraulic fracturing fluids may have flowed vertically along gas well boreholes and then approximately 1 to 3 kilometers (0.62 to 1.9 miles) along shallow and intermediate depth fractures to the aquifer supplying water to the impacted domestic water supply wells. Wastewater from a reported pit leak at the nearest gas well pad may have been a source of the HF fluids. The study provides persuasive evidence of fluid migration from HVHF activity to groundwater supplies (Llewellyn *et al.,* 2015). Responses to comments regarding issues relating to migration of gas and other fluids are presented in Section 2.3.2.3, Pollution from Fluid Migration.

Groundwater contamination resulting from the migration of gas caused by HVHF activities: Local studies have demonstrated that HVHF activities can result in, and have resulted in, the migration of gas to groundwater. Many instances of stray gas migration from HVHF activities to groundwater resources have been documented. Stray gas refers to the phenomenon of natural gas migrating to groundwater, water wells, or to the surface (cellars, streams, or springs). Stray gas can migrate along many naturally occurring or artificially created pathways, including defective production well boreholes and naturally occurring or induced fractures (Soeder, 2017, p. 100-103; U.S. EPA, 2016a, p. 6-23 – 6-25). Numerical analysis has shown that the migration of gaseous methane from a leaking well through an aquifer can be extremely rapid, on the order of minutes (D'Aniello *et al.,* 2019). Not only is methane in groundwater a potential explosion hazard, but a methane plume from a leaking gas well can alter and degrade groundwater quality. A study conducted in New York, Pennsylvania, and West Virginia documented the phenomenon of "gas leak drainage" (GLD), whereby hydrocarbons from leaking gas wells change the subsurface redox environment such that metals are mobilized, and hydrogen sulfide is produced (Woda *et al.,* 2018). The impacted groundwater can discharge to the surface as GLD and impact surface water (Woda *et al.,* 2019). Leaking gas can also potentially degrade groundwater quality by causing deeper groundwater of low quality to be mixed with shallow groundwater. A controlled field study of a subsurface gas release demonstrated the potential for deep saline water to be displaced upward by free phase gas migration, adversely impacting water chemistry in shallow aquifers (Forde *et al.,* 2019b). Documented cases of stray gas migration from HVHF activities are noted below:

In Dimock, PA the Pennsylvania Department of Environmental Protection (PADEP) investigated the cause of groundwater contamination and made a determination that 18 water wells tapping groundwater in the Catskill Formation and located within a nine-square-mile area had been negatively affected by natural gas extraction activities. Although the specific role of hydraulic fracturing in the migration of gas to the Catskill Formation and the specific pathways by which this migration from HVHF activity occurred are uncertain, PADEP concluded that HVHF-related activities were a cause of the migration of methane into the private wells (*see,* PADEP, 2009; PADEP, 2010). Different studies have indicated different sources of the leaked gas. The specific extraction activity causing the migration of gas to the Catskill Formation and the specific pathways by which this migration occurred remain uncertain.

Other documented locations of stray gas from HVHF activities include Bainbridge, OH (22 private domestic wells and one public water supply well affected; ODNR, 2008, p. 6); other areas in Susquehanna and Bradford Counties, PA (9 private domestic wells affected; U.S. EPA, 2015d, p.109); and many other locations in Pennsylvania (PADEP, 2019d). PADEP enforcement actions in response to impacted wells such as those cases in Bradford and Sullivan Counties (PADEP, 2018c), Bradford County (PADEP, 2015b), Nicholson Township, Wyoming County (PADEP, 2017a), Forks Township and Elkland Township, Sullivan County (PADEP, 2016a), and Donegal Township, Westmoreland County (PADEP, 2016b), and elsewhere have been resolved by PADEP-issued Consent Assessment of Civil Penalty or Consent Order and Agreement. Other locations of stray gas migration from HVHF activity are documented by the EPA (U.S. EPA, 2016a, 6-23 - 6-25). In many cases, stray gas in groundwater has been linked to faulty well integrity, a problem that has persisted in the oil and gas industry for decades (PADEP, 2018a), and is especially problematic for HVHF wells, as described in detail in Section 2.3.2.3 (Pollution from Fluid Migration). The complex process of cementing gas wells requires sound engineering judgement in conducting actions on 65 critical parameters, factors, and operational considerations (API, 2010). After the cementing process is complete, the well may experience cyclic stresses during the HVHF process that can open gaps within the well annulus, resulting in leaks (Soeder, 2017, p.72). No American Petroleum Institute standardized protocols exist for cement-testing and evaluation of cement mechanical properties (Carpenter, 2015). Gas wells can develop gas leaks along the casing years after production has ceased and the well has been plugged and abandoned, as shown in a report the U.S. Geological Survey (McMahon *et al.,* 2018). Pennsylvania significantly upgraded its casing and cementing/well construction and operation regulations in 2011 to address issues associated with poorly constructed wells (*see* Appendix-4). However, violations of regulations and impacts to water resources continue to occur.

<u>Studies of groundwater contaminants before, during, and after HVHF activities:</u> The Commission is aware of two studies that examined conditions at a gas well site (or sites) before, during, and after the process of constructing the gas well(s) and initiating gas production in order to determine if migration of gas or fluid occurred between the target formation and overlying formations during the time period of the study. These studies are described below:

One of the studies examined the Marcellus Shale and an overlying Upper Devonian/Lower Mississippian gas field in Greene County, PA (south of Pittsburgh). Monitoring for evidence of fluid migration was performed before, during, and after the hydraulic fracturing of six horizontal Marcellus Shale gas wells. Results of the study indicated that there had been no detectable migration of gas or other fluids from the Marcellus Shale to the overlying Upper Devonian/Lower Mississippian gas field (Hammack *et al.,* 2014). The other study, partly funded by Southwestern Energy, examined shallow groundwater quality before, during, and after drilling, hydraulic fracturing, and initiation of shale gas production in a 25 square-kilometer area in northeastern Pennsylvania targeted for the development of approximately 22 Marcellus Shale wells from four pads. Eight multi-port monitoring wells were installed next to well pads and above or near gas well laterals. Methane concentrations in groundwater from three out of eight monitoring wells increased by over 20 mg/l following the drilling, stimulation, and start of production of the nearest gas well. Salinity of groundwater from the wells likewise increased. However, owing to conflicting results of other chemical analyses, the researchers hypothesized that the increases in methane and salinity were a response to meteorologically driven shifts in aquifer recharge. They concluded that impacts to groundwater from the process of hydraulic fracturing were not detected within the two-year timeframe of the study. The study also found that methane and ethane from the Marcellus Shale had migrated through a gas-well casing rupture and was detected at low concentrations in a monitoring well situated near the ruptured gas well (Barth-Naftilan *et al.,* 2018). This result demonstrates one migration pathway from a shale gas reservoir to groundwater resources.

<u>Groundwater contamination from HVHF activity as evidenced by observations of gas in streams:</u> Leaking gas can migrate to shallow groundwater and to streams and can be observed to bubble up

from the impacted streambed (Grieve *et al.,* 2018; Llewellyn *et al.,* 2015). These situations provide unique opportunities for quantifying HVHF impacts and tracing sources of the gas. The detection of stray gas from HVHF activity by monitoring domestic water-supply wells near gas wells is inefficient because the wells are often not situated along predominant groundwater flow paths and may not intercept migrating gas. In areas where groundwater containing stray gas discharges to streams, the streams can provide an opportunity for monitoring and quantifying stray gas impacts to groundwater at the watershed scale. Several studies were conducted in and around the watershed of a stream with high dissolved methane concentrations located in Lycoming County, PA in an area where many shale gas wells were drilled between 2008 and 2012. A USGS study used a new monitoring concept combining stream hydrocarbon and noble-gas measurements with stream reach mass-balance modeling to estimate thermogenic methane concentrations and fluxes in groundwater discharging to streams (Heilweil *et al.,* 2014). The method can also help identify methane sources. The method was used to investigate methane in streams in northeastern Pennsylvania. Methane concentrations measured in 4 of the 15 streams sampled were greater than or equal to 5 micrograms per liter (≥5μg/L). Geochemical analyses of water from one stream with high methane (Sugar Run, Lycoming County) were consistent with Middle Devonian gases. The stream is near the location of a PADEP investigation of suspected stray-gas migration from a nearby Marcellus Formation gas well. One-dimensional stream-methane transport modeling indicated a groundwater thermogenic methane flux of about 0.5 kilograms per day discharging into Sugar Run, demonstrating the migration of gas from the Marcellus Formation to groundwater feeding the stream. The information from the study of gaining stream reaches integrates information about methane migration to groundwater over kilometer-scale distances that are more representative of regional aquifer conditions than point samples from monitoring wells (Heilweil *et al.,* 2015).

A subsequent study of methane in Sugar Run and other, unimpacted streams used geochemical tracers to identify characteristics related to leaking gas wells. Analyses of hydrocarbon isotopic signatures and radiogenic strontium confirmed consistency with a Middle Devonian Marcellus Formation source. The characteristics observed in the stream near the gas well suspected of leaking included higher concentrations of modern atmospheric age tracers in groundwater than in unimpacted streams. The observed tracer concentrations may indicate upward transport of hydrocarbons as a separate gas phase rather than in solution (Grieve *et al.,* 2018).

Additional study at Sugar Run led by Penn State University identified geochemical signatures that could indicate a subsurface methane plume in groundwater from a leaking gas well. These chemical clues can distinguish methane migration from shale gas development from preexisting methane. The study also provides a coherent geological explanation for why gas migration occurs in the area. Gas may migrate as a result of gas well development in this area because the Marcellus Shale dips significantly, is shallow (about 1 km or 0.6 mi deep) and is naturally more fractured than in other areas (Woda *et al.,* 2018).

<u>Groundwater contamination from the migration of HVHF chemicals from HVHF impoundments</u>: Impacts to groundwater have also resulted from overflows or leaks from impoundments storing HVHF produced water. In 2015, produced water was discharged through holes in the liners of HVHF fluid impoundments operated by Energy Corporation of America in Greene County, PA, and Clearfield County, PA. The releases impacted surface water, groundwater, and a spring used for domestic supply. In addition to a civil penalty of $2,250,000, the PADEP-issued Consent Order and Agreement required the operator to remediate, monitor, and restore the release sites (PADEP, 2017c).

An HVHF fluid impoundment operated without a permit by EQT Production Company in Duncan Township, Tioga County, PA had as many as 200 holes in its lining, which resulted in leaked flowback and produced water that created a plume of contaminated groundwater extending at least 2,000 feet (the largest aerial extent of groundwater contamination in the history of the program). The discharge impacted Rock Run, a Class A Wild Trout stream and a High Quality stream draining a watershed that contains Exceptional Value wetlands. Trees and shrubs along the discharge flow path also were severely impacted. As part of site remediation, at least 35 million gallons of contaminated water were collected. Judge Labuskes of the Environmental Hearing Board described "EQT's conduct with respect to the construction, operation, and closure of the impoundment and early remediation of the release" as "reckless" and imposed a fine of $1,137,295 (PADEP, 2017d; *also see,* PADEP 2014a (DEP press release announcing in excess of $4.5 million in penalties sought)). EQT was also reportedly charged with six criminal misdemeanors (Colaneri, 2014b).

The Commission notes that operators may no longer use centralized impoundments to store unconventional well wastewater in Pennsylvania without first obtaining a residual waste storage permit. More details on incidents of HVHF fluid releases from spills and HVHF impacts to drinking water resources are presented in Section 2.3.2.2 (Pollution from Spills) and Section 2.3.3.1 (Drinking Water Resources).

The local studies described above demonstrate that HVHF activities can result in, and have resulted in, subsurface migration of fluids, including gas, and subsequent adverse impacts to groundwater.

Regional Impacts to Groundwater

Many field studies have been conducted to identify HVHF impacts to groundwater resources on a regional basis and to further understand possible mechanisms and pathways for HVHF fracturing fluid, produced water, and gas migration to shallow aquifers. Regional studies in northeastern Pennsylvania and New York are discussed first, followed by regional studies in other shale gas areas. The findings of this type of research are sometimes controversial.

<u>Background groundwater quality</u>: An understanding of background groundwater quality conditions and the natural processes and factors contributing to background groundwater quality is critical to the detection and understanding of changes in groundwater quality resulting from human activities including the development of natural gas in unconventional formations. Studies of pre-drilling groundwater quality in the Appalachian Basin, for example, showed that natural groundwater quality in the region commonly exceeds one or more regulatory guidelines and commonly exceeds the analytical detection limit for methane (Siegel *et al*., 2015b, 2016). Investigations of groundwater quality and gases can also provide clues about the presence or absence of naturally occurring pathways that could make aquifers more vulnerable to the migration of HVHF fluids. USGS assessments of baseline groundwater quality in Pike County, and Wayne County, PA found that shallow (less than about 1,000 feet deep) groundwater generally meets primary drinking-water standards for inorganic constituents. Methane concentrations in groundwater from 24 percent of the sampled wells in Pike County were greater than the laboratory reporting limit of 0.01 mg/l. In Wayne County, methane concentrations in groundwater from 9 percent of sampled wells were greater than the laboratory method reporting limit of 0.24 mg/l. In both counties, methane concentrations in groundwater from most sampled wells were below respective laboratory method reporting limits. Water quality varies spatially, with methane (up to 2.5 mg/l and 9.6 mg/l, respectively) and some constituents found in high

concentrations in brine (and connate waters from gas and oil reservoirs) present at low to moderate concentrations in some parts of both counties (Senior and Cravotta, 2017a; Senior and Cravotta, 2017b). A study of 1701 water wells in Susquehanna County, Pennsylvania found that methane is common in groundwater, with higher concentrations observed in valleys in comparison with concentrations in upland areas (Molofsky *et al.,* 2013). These studies show that methane and gas reservoir brine constituents occur in groundwater in these counties of northeast Pennsylvania. Determining the sources of methane and brine constituents in groundwater is the subject of much research in the region.

Evidence of groundwater contamination from HVHF activities in Pennsylvania: Identifying the source of stray gas typically involves the analysis of noble gases and their isotopes that can be used in matching the composition in the stray gas with that of potential source gases. The first study to conduct a comprehensive analysis of noble gases and their isotopes in groundwater near shale-gas wells was led by Duke University and published in 2014 (Darrah *et al.,* 2014). The study distinguished natural sources of methane from anthropogenic contamination and evaluated the mechanisms that cause elevated hydrocarbon concentrations in drinking water near natural gas wells. Stray gases in eight clusters of domestic water wells overlying the Marcellus and Barnett Shales were analyzed. In four of the eight clusters, gas geochemistry data implicated gas originating from intermediate-depth non-target strata that leaked through faulty gas-well annulus cement. In three cases, the analysis implicated gas originating from the target formation that leaked through faulty production casings. In one case, the analysis implicated gas originating in the target formation that leaked due to a documented underground well failure. Prior studies by Duke University in 2011 and 2013 found elevated concentrations of methane in some private wells located less than 1 kilometer (0.6 miles) from unconventional gas wells and that methane concentrations increased with proximity to the gas wells. The 2013 study found that concentrations of ethane and propane were also higher in wells proximal to unconventional gas wells (Jackson *et al.,* 2013b; Osborn *et al.,* 2011). A 2018 study of 11,000 predrill samples from private domestic water wells in Bradford County, PA by Penn State University utilized data mining techniques and found a few clusters of "hot spots" where methane concentrations were slightly elevated in domestic water wells located near recently drilled unconventional and conventional gas wells (Wen *et al.,* 2018). Results of these studies provide strong evidence that some gas production wells are adversely impacting groundwater in parts of northeastern Pennsylvania and elsewhere. In contrast with these results, an industry-funded study of an industry-provided database of analytical results for Bradford and nearby counties in Pennsylvania found no relation between dissolved methane concentrations in groundwater and proximity to oil or gas wells that were already in operation at the time of the collection of groundwater samples (Siegel *et al.,* 2015a).

The USGS conducted studies of groundwater quality in two Pennsylvania counties—Bradford and Lycoming—where extensive shale-gas development had occurred (Clune and Cravotta, 2019; Gross and Cravotta, 2017). Both studies found that groundwater quality in these counties generally met most drinking-water standards, but that in some parts of the aquifer, methane and some constituents that occur in high concentrations in naturally occurring brine and produced waters from gas and oil wells were present at low-to moderate concentrations. The study results did not indicate whether the presence of methane and brine constituents was a result of natural geochemical processes or of gas and oil development.

A 2019 study by the USGS examined water samples from 50 domestic wells located <1 kilometer (proximal) and >1 kilometer (distal) from shale-gas wells in upland areas of the Marcellus Shale region and analyzed chemical, isotopic, and groundwater-age tracers. The study concluded that one of the proximal samples contained thermogenic methane (2.6 mg/L) from a relatively shallow source (Catskill/Lock Haven Formations) "*that appears to have been mobilized by shale-gas production activities*." (McMahon *et al.,* 2019). This study, and studies in the Marcellus region described above, provide compelling evidence of the migration of Marcellus Shale gas from leaking gas wells and mobilized gas from intermediate strata to groundwater and a stream and demonstrate that aquifers in some areas in northeastern Pennsylvania could be more vulnerable to gas migration due to HVHF activities as a result of geological conditions.

Many substances used in or resulting from hydraulic fracturing activity are known endocrine disruptors (EDCs), which are potentially dangerous at extremely low concentrations. The full effects of EDCs on public health and wildlife populations are not currently known. Research has investigated the presence of endocrine disrupting chemical activity in groundwater and surface water near HVHF activity. A 2019 study of surface water and groundwater in Susquehanna County, PA, employed a new approach to characterize biological consequences of pollutants in samples and the pollutants that may be responsible (Bamberger *et al.,* 2019). Samples were collected from 33 private wells, 6 streams, 9 ponds, 4 springs, and one lake. Sample proximity to various natural gas infrastructure, including gas wells, compressor stations, and gas dehydrators was determined. Natural gas wells in the county with known casing, cement sheath, and/or other impairments were also identified. The researchers assessed potential toxicity and endocrine activity of the samples with biological assays and determined chemical composition in bulk. The bulk chemical characterizations were then screened for association with anthropogenic activities. One of the biological assays conducted measures aryl hydrocarbon (Ah) receptor activity, which is an indicator of potential immunotoxicity. Other biological assays were conducted to assess endocrine disruption. Ah receptor activity exhibited a strong correlation with proximity to impaired natural gas wells. Endocrine receptor (ER) activities did not show such a correlation. It is not clear whether this lack of correlation is due to the absence of endocrine disrupting substances contributed by HVHF activity or simply the fact that other activities, such agriculture, also contributed to the results. ER activity was found to be associated with potential hydraulic fracturing chemicals or wastewater constituents detected in some samples. The study detected 17 potential hydraulic fracturing additives or wastewater constituents that were associated with Ah activity, ER activity, and proximity to impaired wells. The study authors concluded that the association of these chemicals with biological activity and impaired wells suggests that anthropogenic activities, including hydraulic fracturing operations, have resulted in water contamination. Studies that found evidence of endocrine disrupting impacts from HVHF activities in other shale gas regions across the nation are presented below and in Section 2.3.3.1 (Drinking Water Resources).

Some studies of groundwater quality have identified spills of HVHF fluids as the source of groundwater contamination. A 2015 study led by Yale University investigated the source of organic chemicals in groundwater samples from private residential wells in northeastern Pennsylvania. Based on analyses of organic compounds coupled with inorganic geochemical fingerprinting, estimates of groundwater residence time, and geospatial analyses of shale gas wells and disclosed safety violations, the investigators determined that the dominant source of organic compounds in shallow aquifers was consistent with the accidental release of fracturing fluid chemicals from surface spills rather than subsurface migration of these fluids from the underlying shale formation (Drollette *et al.,* 2019).

Evidence of groundwater contamination from HVHF activities in other regions: Other studies have found evidence of shallow groundwater impacts from unconventional gas development in areas other than the northeastern Marcellus region. Results are summarized below. Details of some of the studies are presented in Section 2.3.2.3, Pollution from Fluid Migration, and in Section 2.3.3.1, Drinking Water Resources.

A 2013 assessment examined water quality in aquifers overlying the Barnett Shale formation of North Texas. Researchers at the University of Texas analyzed samples from 100 private drinking water wells using analytical chemistry techniques. Analyses revealed that arsenic, selenium, strontium and total dissolved solids (TDS) exceeded the Environmental Protection Agency's Drinking Water Maximum Contaminant Limit (MCL) in some samples from private water wells located within 3 km of active natural gas wells. Lower levels of arsenic, selenium, strontium, and barium were detected at reference sites outside the Barnett Shale region as well as at sites within the Barnett Shale region located more than 3 km from active natural gas wells. Methanol and ethanol were detected in 29 percent of samples. Samples exceeding MCL levels were randomly distributed within areas of active natural gas extraction, and the spatial patterns in the data suggest that elevated constituent levels could be due to a variety of factors including mobilization of natural constituents, hydrogeochemical changes from lowering of the water table, or industrial accidents such as faulty gas well casings (Fontenot *et al.,* 2013). Further study in the region examined 550 groundwater samples collected from private and public supply water wells. The results detected multiple volatile organic carbon compounds throughout the region, including various alcohols, BTEX compounds, and several chlorinated compounds. These results do not necessarily identify HVHF activities as the source of contamination; however, many of the compounds detected are known to be associated with HVHF activities (Hildenbrand *et al.,* 2015). A 2016 geospatial analysis of groundwater quality data in the Barnett Shale region was conducted by the University of Houston and the University of Texas to determine if regional variations in groundwater quality may be associated with the presence of HVHF wells in the region. Results indicated that elevated concentrations of some groundwater constituents are likely related to natural gas production in the study area and that beryllium could be used as an indicator variable for evaluating fracturing impacts on regional groundwater quality. Results also indicated that gas well density and formation pressures correlate to changes in regional groundwater quality, whereas proximity to gas wells, by itself, does not. The results also provide indirect evidence supporting the possibility that microannular fissures may be pathways transporting fluids and chemicals from the fractured wellbore to the overlying groundwater aquifers (Burton *et al.,* 2016).

Results of a 2017 study by USGS on methane, benzene, and groundwater-age tracers in the Eagle Ford, Texas, Fayetteville, Arkansas, and Haynesville, Texas/Louisiana shale gas regions indicate that benzene detected in some wells was from subsurface sources such as natural hydrocarbon migration or leaking hydrocarbon wells. Methane isotopes and hydrocarbon gas compositions indicate most of the methane in the wells was biogenic and not from thermogenic shale gas. Two samples contained methane from the fermentation pathway that could be associated with hydrocarbon degradation based on their co-occurrence with hydrocarbons such as ethylbenzene and butane. The study also examined groundwater-age tracers (tritium, SF6, carbon-14, and tritiogenic helium-3), and used concentrations of these tracers to determine fractions of post-1950s groundwater in the samples and mean ages of the pre- and post-1950s fractions. Pre- and post-1950s groundwater are defined as water entering an aquifer as recharge before or after, respectively, the early 1950s start of above-ground nuclear weapons testing. The above-ground detonation of nuclear bombs releases tritium into the atmosphere, where it is adsorbed by rainfall and can enter aquifers with recharge and acts as a groundwater-age tracer. Groundwater travel times inferred from tracer age data of this study indicate that decades or longer may be needed to fully assess the effects of potential subsurface and surface releases of hydrocarbons on groundwater quality in these regions (McMahon *et al.,* 2017). This important result indicates that even when elevated concentrations of contaminants are not detected, they may reach aquifers in the future.

A community-based study of 66 residences in and near Belmont County in eastern Ohio explored HVHF well proximity in relation to water contamination and health symptoms. Contaminants analyzed included volatile organic compounds (VOCs), gasoline-range organics, and diesel-range organics. The study, led by Yale University, found that contaminant detection and concentrations increased with proximity to HVHF gas wells. The study also found that HVHF well proximity was also associated with increased general health symptoms (e.g. fatigue) (Elliott *et al.,* 2018).

A 2013 study examined publicly available data regarding groundwater contamination from HVHF spills in Weld County, Colorado. From July 2010 to July 2011, there were 77 reported surface spills impacting groundwater. Measurements of the four BTEX components exceeded EPA's national drinking water maximum contaminant levels (MCLs) in 90, 30, 12, and 8 percent of the samples, respectively. The analysis demonstrates that surface spills are an important risk of potential groundwater contamination from hydraulic fracturing activities (Gross *et al.,* 2013).

In a study of endocrine disrupting activity in Colorado, most of the surface water and groundwater samples collected from sites in a region of dense oil and gas development exhibited more estrogenic, anti-estrogenic, or anti-androgenic activities than reference sites with limited nearby oil and gas operations. These results suggest that natural gas drilling operations may result in elevated endocrine disrupting chemical activity in surface and ground water (Kassotis *et al.,* 2014).

In a Wyoming study, groundwater samples from HVHF gas-production areas and conventional oil production areas exhibited greater estrogen receptor (ER) antagonist activities than water samples from conventional gas production areas. Samples from HVHF gas production areas tended to exhibit progesterone receptor antagonism more often, suggesting there may be a HVHF-related impact on this endocrine activity (Kassotis *et al.,* 2018). Studies of surface waters near HVHF activities in North Dakota and West Virginia also found evidence of elevated endocrine disrupting chemical activity (Cozzarelli *et al.,* 2017; Kassotis *et al.,* 2016). Interviewed about this body of research on endocrine disruption, senior author Christopher Kassotis of Duke University summarized it this way:

> We have now reported similar endocrine bioactivities across numerous unconventional oil/gas sampling regions, and other researchers are beginning to demonstrate similar effects in cell and animal models. These, above all else, lend strong support for our findings.

(Thuermer, 2018). The studies noted above document evidence of impacts of HVHF activities to groundwater in many areas outside the Delaware River Basin including northeastern Pennsylvania, Ohio, Texas, Colorado, North Dakota, and Wyoming. Other studies of groundwater quality in regions other than the northeastern Marcellus region did not find evidence of impacts (Harkness *et al.,* 2017; Hildenbrand *et al.,* 2017; Wen *et al.,* 2016; Warner *et al.,* 2013b). Some studies in the Barnett Shale region that used noble gases and other methods suggested that the source of stray gas was local gas accumulations known to be present in the shallow subsurface, and not the result of hydraulic fracturing activity(Larson *et al.,* 2018; Nicot *et al.,* 2017; Wen *et al.,* 2016).

Although the conclusions of the various studies are not uniform, in many locations HVHF activities have adversely impacted private drinking water wells with stray gas and other contaminants, and proximity of the drinking water wells to gas wells can be an important factor in predicting the likelihood of such impacts.

The weight of evidence presented by the local and regional studies noted above, in Section 2.3.3.1 (Drinking Water Resources), Section 2.3.2.3 (Pollution from Fluid Migration), and in the reports by EPA and the NYSDEC, indicates that HVHF activities have impacted groundwater resources, and that the presence of permeable geologic structures in some areas may contribute to increased vulnerability of aquifers in northeastern Pennsylvania to HVHF impacts, especially contamination from stray gas and fluid spills. As a result of long groundwater travel times, the effects of potential subsurface and surface releases of hydrocarbons on groundwater quality may take decades or longer to be fully assessed.

Statement of Concern (SC-65)

Pumping of aquifers has the potential to cause a groundwater pollution plume to move toward the pump location, spreading the pathway of pollution and/or the rate of movement.

Response (R-65)

The Commission acknowledges the effect aquifer withdrawals can have on groundwater flow patterns and the migration of contaminant plumes. This effect is central to a principal management technique, called "pump and treat," used to control the migration of groundwater contamination from Superfund sites (U.S. EPA, 1996). The containment, management, and remediation of specific occurrences of groundwater contamination is conducted under federal and state environmental programs.

Statement of Concern (SC-66)

Considering that one percent of the earth's water is drinkable, how we manage water will define our future and the future of the planet. Since 99 percent of the water is groundwater, how we look after our aquifers is the most critical component.

Response (R-66)

The DRBC acknowledges and affirms the commenter's focus on the importance of groundwater resources. The DRBC's Comprehensive Plan and Water Code provide that the quality of the Basin's groundwater shall be maintained in a safe and satisfactory condition for uses that include public water supplies, except where such uses are precluded by natural quality. These and other provisions and policies ensure that the DRBC's responsibility to provide comprehensive water resource management can be fulfilled. The regulations are intended to prevent any adverse impacts to water resources in the Delaware River Basin from activities associated with high volume hydraulic fracturing.

Impacts to groundwater - Summary

The Commission's responses to the numerous comments it received on potential impacts to groundwater, based on the staff's careful evaluation of a decade of scientific data and literature on this subject, are summarized below:

- The activities and materials associated with unconventional gas development can result in and have resulted in significant adverse impacts to groundwater.
- The potential for impact from HVHF water acquisition on groundwater availability at the watershed scale appears to be small, and local effects can be effectively managed.
- HVHF fluid and natural gas is more likely to migrate through poorly constructed or abandoned gas wells than solely through natural faults and fractures, and gas is more likely than fluid to migrate in this manner.
- Adverse impacts to groundwater are known to have resulted from spills, well injection, and leaking gas well boreholes.
- Methane from a leaking HVHF borehole in Pennsylvania has migrated to groundwater and to a stream. Monitoring methane and in streamflow provides the basis for quantifying and monitoring the flux of methane reaching the stream.
- Aquifers in some areas of northeastern Pennsylvania may be more vulnerable to fluid migration from HVHF activities as a result of geological conditions.
- Several studies have been conducted using different approaches and in different areas to determine the presence or absence of geologic features with relatively high permeability that could potentially provide pathways for subsurface migration of HVHF fluids (including gas) to shallow groundwater. Results of many studies of the Marcellus region in northeastern Pennsylvania and New York suggest the presence of such features.
- Assessments of shallow groundwater quality in different areas of unconventional oil and gas development across the nation have been conducted. A study of the Eagle Ford region in southern Texas, the Fayetteville region in Arkansas, and the Haynesville region of Texas and Louisiana found that benzene detected in some wells originated from subsurface sources such as natural hydrocarbon migration or leaking hydrocarbon wells. Studies in the area of the Barnett Shale in northern Texas found evidence of adverse effects on groundwater quality from HVHF activity. Many of the compounds detected in groundwater in the study region are known to be associated with HVHF activities. Other studies in regions other than the northeastern Marcellus region found no evidence that HVHF activity has affected groundwater quality. Groundwater travel times inferred from age data by the USGS indicate that decades or longer may be needed to fully assess the effects of potential subsurface and surface releases of hydrocarbons on groundwater quality in these regions.
- Results of studies in Colorado and Pennsylvania indicated that the likely source of organic contaminants detected in groundwater was HVHF fluid spills.

- Comments minimizing the risks of HVHF to groundwater are not consistent with the weight of the scientific evidence, the record of industry safety and compliance with regulations, or with other factors that contribute to the risks posed by HVHF to groundwater.
- The Commission agrees with and relies on the EPA's understanding and interpretation of the peer-reviewed scientific research published through 2016, as set forth in its 2016 report, Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. This understanding includes the EPA's conclusions that hydraulic fracturing activities can adversely affect water resources under some circumstances and that these impacts can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors.
- The Commission agrees with and relies on the 2015 Final Supplemental Generic Environmental Impact Statement on [New York's] Oil, Gas and Solution Mining Regulatory Program prepared by the NYSDEC, which found that the adverse environmental impacts that could result from high volume hydraulic fracturing may have adverse public health outcomes, including drinking water impacts from underground migration of methane and/or fracturing fluid chemicals associated with faulty well construction or seismic activity.
- After publication of the NYSDEC SGEIS Findings Statement in 2015 and EPA's final report on Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States in 2016, additional research was published reinforcing NYSDEC's and EPA's conclusions and providing additional compelling evidence that HVHF may be accompanied by adverse impacts to groundwater.

The Commission has determined that if HVHF were permitted and commercially recoverable gas were present in the Delaware River Basin, HVHF would be performed at dozens or hundreds of well pad sites in the Basin, primarily: in rural areas dependent upon groundwater resources, in sensitive headwater areas considered to have high water resource values, in areas draining to DRBC Special Protection Waters, and in a region characterized by extensive geologic faults and fractures. Adverse impacts to groundwater would inevitably occur as the result of discharges of harmful pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined.

A decade of experience in other regions has shown that regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills, gas migration, and releases of chemicals and hydraulic fracturing wastewater. Accordingly, the Commission has determined that controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.3.4 Wetlands

Many commenters expressed concerns about potential impacts to wetlands from a variety of HVHF activities, including water withdrawals, the generation of radioactive wastes, the construction and maintenance of infrastructure, and other activities that could degrade the quality of water supporting wetlands.

Statement of Concern (SC-67)

Many commenters expressed concerns that withdrawals from groundwater and surface water for HVHF activities will harm wetlands, other water-dependent habitats, and associated biota, including rare, threatened and endangered species. Representative, paraphrased examples of specific concerns about impacts of HVHF withdrawals on wetlands include the following:

- Withdrawals from surface and ground water in the amounts required for HVHF may adversely affect aquatic ecosystems and river channels and riparian resources downstream, including wetlands.

- Pumping of aquifers has the potential to disrupt the flow of groundwater that feeds existing water supply wells or natural resources such as wetlands, seeps, and springs.

- There are many documented harms of inter-basin transfers, including reduced flow rates in the donor basin: decreased supply in the donor basin can result in changes to a waterbody's natural flow patterns, with impacts to native vegetation and aquatic habitats, including wetlands.

- Given the extraordinary ecological diversity known to exist within the Special Protection Waters in the upper portion of the Delaware River Basin in Pennsylvania, it is imperative that any further discussion of proposals to allow water withdrawals and disposal of fracking wastewater into the waters of the Delaware River Basin must be accompanied by a complete and through Biological Assessment as to how bog turtles and the thousands of other species of concern in northeast Pennsylvania will be affected, both individually and collectively.

Response (R-67)

DRBC fulfills the resource management charge conferred on it by the interstate and federal statute known as the Delaware River Basin Compact through policies, regulations and practices informed by science. As DRBC's policy set forth in its Comprehensive Plan and codified in the Delaware River Basin Water Code states:

> The quality of Basin waters, except intermittent streams, shall be maintained in a safe and satisfactory condition for the following uses:
>
> 1. agricultural, industrial, and public water supplies after reasonable treatment, except where natural salinity precludes such uses;
>
> 2. wildlife, fish and other aquatic life;
>
> 3. recreation;
>
> 4. navigation;
>
> 5. controlled and regulated waste assimilation to the extent that such use is compatible with other uses;

6. such other uses as may be provided by the Comprehensive Plan.

(Water Code, § 3.10.2 B.).

The Commission's Comprehensive Plan and Water Code further provide that:

> It shall be the policy of the Commission to support the preservation and protection of wetlands by:
>
> A. Minimizing adverse alterations in the quantity and quality of the underlying soils and natural flow of waters that nourish wetlands.
>
> B. Safeguarding against adverse draining, dredging or filling practices, liquid or solid waste management practices, and siltation.
>
> C. Preventing the excessive addition of pesticides, salts or toxic materials arising from non-point source wastes.
>
> D. Preventing destructive construction activities generally.

(Water Code, § 2.350.2).

Threats to wetlands from HVHF activities include those relating to water use, land use changes, and contamination of waters sustaining wetlands (Sutter *et al.,* 2015). The Commission acknowledges that under certain conditions withdrawals from surface waters and groundwaters for any purpose may adversely affect nearby and downstream users, and water-dependent habitats including wetlands, and associated biota (U.S. EPA, 2015b, pp. 1-4; Alley, *et al.,* 1999). The New York DEC Final Supplemental Generic Environmental Impact Statement on hydraulic fracturing explains the issue this way:

> The functioning of a wetland is driven by the inflow and outflow of surface water and/or groundwater. As a result, withdrawal of surface water or groundwater for high-volume hydraulic fracturing could impact wetland resources. These potential impacts depend on the amount of water within the wetland, the amount of water withdrawn from the catchment area of the wetland, and the dynamics of water flowing into and out of the wetland. Even small changes in the hydrology of the wetland can have significant impacts on the wetland plant community and on the animals that depend on the wetland.

(NYSDEC, 2015a, p. 6-5). Section 2.3.3.1, Water Use, provides more detailed discussion of potential water uses and consumptive water uses associated with high volume hydraulic fracturing.

The EPA conducted a study of the impacts of HVHF water acquisition on water availability, including impacts to surface water and groundwater. The study included a detailed analysis of these impacts from the Marcellus Shale development in the Susquehanna River Basin. The study concluded that the potential for hydraulic fracturing impact on groundwater and surface water availability at the watershed scale appears to be small, and that local impacts to surface water availability in small streams can be effectively managed (U.S. EPA, 2015b, pp. 1-2). Additional details of this study are discussed in Section 2.3.3.2, Surface Water and Aquatic Life, and Section 2.3.3.3, Groundwater. These sections also discuss impacts of HVHF activities to water resources from releases of fracturing fluids, flowback, and produced water. After carefully considering the public comments received on the draft rules, the Commission is withdrawing from consideration the provisions of such rule relating to the exportation of water from the Delaware River Basin for hydraulic fracturing and related activities (Section 440.4). The topic of water exportation will be addressed through one or more separate Commission actions.

As proposed in the draft rules and as discussed and supported throughout this comment response document, high volume hydraulic fracturing and related activities would be prohibited within the Delaware River Basin. As such, impacts to wetlands from water withdrawals to support high volume hydraulic fracturing in the Basin will not occur.

Statement of Concern (SC-68)

A commenter expressed concern about the problem of radioactive waste in landfills, including those occupying wetlands or within dangerous proximity to wetlands. The Hakes landfill in Painted Post, NY was presented as an example of a landfill found to contain an inordinate amount of radium-derived radionuclides in the areas of the landfill where HVHF waste has been dumped.

Response (R-68)

Regulation of solid waste disposal is not a matter addressed by the Final Regulations. The regulation of the types of materials and the methods by which they can be disposed of at landfills is regulated by the EPA and/or the individuals states. EPA guidelines allow for waste material containing low-level activity waste to be accepted at landfills. Naturally occurring radioactive materials (NORM) extracted from drilling may be considered low activity wastes (U.S. NRC, 2017).

As for concerns about leachate entering the water cycle, EPA regulations at 40 C.F.R. Part 258 for the implementation of Subtitle D (non-hazardous solid waste) of the Resource Conservation and Recovery Act (RCRA), regulate the construction and operation of landfills (U.S. EPA, 2020b). These regulations require operators to:

1. ensure that landfills are built in suitable geological areas away from faults, wetlands, flood plains or other restricted areas;

2. line the bottom and sides of landfills with composite liners consisting of a geo-membrane overlying two feet of compacted clay soil;

3. install and operate leachate collection and removal systems;

4. monitor groundwater wells to determine whether waste materials have escaped from the landfill;

5. develop and implement closure and post closure plans to ensure closed landfills are covered and to provide long-term care of closed landfills; and

6. implement corrective action to control and clean up landfill releases and achieve groundwater protection standards.

7. provide financial assurance to ensure proper closure and post-closure care.

See summary at: https://www.epa.gov/landfills/municipal-solid-waste-landfills. The DRBC will continue to review any proposed discharge of treated leachate as a discharge of industrial wastewater, when such discharges are at and above the thresholds described in 18 C.F.R. §§ 401.35(a)(5) and (b)(8). The DRBC also intends to continue to review the importation of leachate into the Basin under existing review thresholds at 18 C.F.R. §§ 401.35(a)(18) and (b)(4) and under existing exportation and importation regulations at Section 2.30 of the Water Code.

Statement of Concern (SC-69)

Allowing the construction and maintenance of hydraulic fracturing infrastructure such as pipelines would have a high potential for damaging our aquifer through the destruction of wetlands and headwaters that feed and maintain the purity of the aquifer.

Response (R-69)

The Commission acknowledges the importance of wetland areas and headwaters streams to the integrity of downstream water resources, although the role of these features in recharging aquifers is limited in most areas and in most circumstances. Most aquifer recharge in the Delaware River Basin occurs as infiltration of precipitation over the land surface (Parker *et al.,* 1964). Wetlands are important for removal of some pollutants that could potentially impact aquifers and can help in contributing aquifer recharge in some areas, under some circumstances (Tiner and Wilen, 1988). Headwaters streams usually receive flow from groundwater rather than contributing recharge to aquifers, but they can contribute to aquifer recharge in some settings and under some circumstances, as has been shown by the U.S. Geological Survey, for example, in streams near Altoona, PA (Cravotta *et al.,* 2018). Headwaters streams are important sources of sediments, nutrients, and organic matter (Gomi *et al.,* 2002). In undeveloped areas, any aquifer recharge from headwaters streams can be expected to be low in anthropogenic contaminants.

No amendment was proposed to the Commission's existing regulations regarding the review of natural gas transmission lines. Subpart C of the Rules of Practice and Procedure (18 C.F.R. Part 401) ("Rules") governs the submission and review pursuant to Section 3.8 of the Delaware River Basin Compact, of projects having a substantial effect on the water resources of the Basin. Among other things, the Rules identify multiple categories of projects that are presumed not to have a substantial effect on the Basin's water resources and thus are not required to undergo the Commission's review and approval. Among the activities ordinarily not subject to DRBC review are natural and manufactured gas transmission lines and appurtenances, *except* where such lines would:

1. "pass in, on, under or across an existing or proposed reservoir or recreation project area as designated in the Comprehensive Plan" (18 C.F.R. 401.35(a)(12)); or

2. "involve significant disturbance of ground cover affecting water resources" (i.e., involving disturbance of 3 or more square miles) (18 C.F.R. 401.35(a)(12)); or

3. “involve draining, filling or otherwise altering marshes or wetlands when the area affected is greater than 25 acres” (18 C.F.R. 401.35(a)(15)); or

4. involve hydrostatic testing that results in discharges equal to 10,000 gallons per day (gpd) or greater within the drainage area of Special Protection Waters and 50,000 gpd or greater elsewhere in the Basin (*see,* 18 C.F.R. 401.35(a)(5)).

When it reviews pipeline projects, the Commission, among other things, evaluates whether they comply with applicable requirements of the wetlands regulations cited above in Response R-67.

Statement of Concern (SC-70)

The Delaware Riverkeeper Network expressed concern that wetlands are sensitive to development activities and are documented to have been degraded by oil and gas development, and that there is substantial potential for destruction and loss of wetlands if HVHF were to occur in the Basin. HVHF wastewater can pollute streams and wetlands, rendering them unsuitable for many salt-sensitive freshwater organisms including frogs, salamanders, fishes, and many freshwater plants

Another commenter noted that some impacts of erosion from pad site construction, access road development, widening of existing roads, installation of pipelines, and placement of production facilities can be controlled with the use of various Best Management Practices (BMPs) such as protecting bare soils from the wearing effects of water and wind and by reducing or preventing soils from being transported offsite to a stream, surface water body, or wetland.

Response (R-70)

The DRBC acknowledges the concerns raised by commenters surrounding land disturbance and related impacts associated with many aspects of hydraulic fracturing operations, including fluid releases.

Adverse impacts from land disturbance related to HVHF can be severe. For example, in Greene County, PA, in 2012, an HVHF operator failed to implement effective erosion and sedimentation control BMPs, resulting in a landslide that developed on a large fill slope at a well pad, causing fill material to encroach into two unnamed tributaries of Grimes Run. Impacts included deforestation of a forested wetland (PADEP, 2014d).

Wetlands have also been adversely impacted by the release of HVHF fluids. EPA documented that between January 2006 and April 2012 in Texas and Pennsylvania, spills of HVHF flowback, produced water, and chemicals occurred that impacted wetlands (U.S. EPA, 2015e, Appendix B). For example, in Dimock, PA, in 2009, 8,000 gallons of HVHF produced water spilled into Stevens Creek due to the failure of a supply pipe. The contamination caused a fish kill and impacted nearby wetlands (Considine, 2012). Responses to comments on spills are presented in Section 2.3.2.2, Pollution from Spills.

We also acknowledge that a portion of land disturbance impacts can be mitigated and that the initial footprint of disturbance may be reduced over time. Notwithstanding, the Final Regulations prohibit HVHF in the Delaware River Basin; thus, the range of estimated land disturbance associated with hydraulic fracturing operations along with the potential for adverse impacts are not anticipated.

Section 2.3.2.5, Landscape Changes, discusses the risks and vulnerabilities of landscape changes associated with high volume hydraulic fracturing in greater detail. Section 2.3.3.2 further discusses impacts to surface waters and aquatic life.

Statement of Concern (SC-71)

Hydraulic fracturing and its associated water quality issues are just too much for a small State like Delaware with large amounts of wetlands and other areas that could be affected.

Response (R-71)

The Final Regulations prohibit HVHF in the Delaware River Basin; thus, the range of estimated impacts associated with hydraulic fracturing operations, as described above and in other sections of this document, are not anticipated to impact wetlands in Delaware.

Impacts to wetlands - Summary

The Delaware River Basin Compact requires the Commission to develop and adopt a Comprehensive Plan for the immediate and long range development and use of the water resources of the Delaware River Basin. (Compact, §§ 3.2(a) and 13.1. The Compact also confers on the Commission the power to "assume jurisdiction to control future pollution . . . in the waters of the Basin whenever it determines after investigation and a public hearing upon due notice that the effectuation of the comprehensive plan so requires." (Compact § 5.2). *See* Section 1.9 of this Comment and Response Document.

The Commission's Comprehensive Plan and Water Code provide:

> It shall be the policy of the Commission to support the preservation and protection of wetlands by:
>
> A. Minimizing adverse alterations in the quantity and quality of the underlying soils and natural flow of waters that nourish wetlands.
>
> B. Safeguarding against adverse draining, dredging or filling practices, liquid or solid waste management practices, and siltation.
>
> C. Preventing the excessive addition of pesticides, salts or toxic materials arising from non-point source wastes.
>
> D. Preventing destructive construction activities generally.

(Water Code, § 2.350.2).

The Commission's responses to the numerous comments it received on potential impacts to wetlands are summarized below:

- The Commission acknowledges that withdrawals from surface waters and groundwaters for any purpose can adversely affect nearby and downstream users, and water-dependent habitats including wetlands, and associated biota. The potential for hydraulic fracturing impact on groundwater and surface water availability at the watershed scale appears to be small, and local impacts to surface water availability in small streams and wetlands can be effectively managed.

- In locations where HVHF has been conducted, spills of HVHF fluids have occurred that impacted wetlands. If HVHF were allowed in the Delaware River Basin, spills would occur that are likely to adversely affect wetlands. *See generally,* Section 2.3.2.2 of this Comment and Response Document.

- Because DRBC does not regulate solid waste disposal in landfills, the Final Regulations do not address disposal of radioactive waste in landfills, including those occupying wetlands or within proximity to wetlands. DRBC does regulate the discharge of treated leachate pursuant to its existing regulations when the discharge meets the threshold for review in the Rules of Practice and Procedure.

- The regulation of pipelines to transport natural gas or any other substance is not within the scope of the Final Regulations, nor has the DRBC proposed to amend its existing regulations and authority in that respect.

  As proposed in the draft rules and as discussed and supported throughout this Comment and Response Document, the regulations prohibit high volume hydraulic fracturing within the Delaware River Basin. As such, impacts to wetlands associated with the activity will not occur. On the basis of its review, the Commission has determined that some of the risk to wetlands associated with land disturbance that accompanies HVHF could be effectively managed through regulation if this were the only such risk associated with HVHF. However, in light of the other risks and impacts discussed in this document, the potential for adverse impacts to wetlands associated with HVHF activities, combined with the totality of the risks, vulnerabilities, impacts, and uncertainties discussed throughout this comment and response document, supports the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters and wetlands of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.3.3.5 Flood Plains

There were no significant comments provided specific to impacts to flood plains. Some commenters expressed concern with fossil fuel development and climate change and the potential for increased flood risks. Sections 2.6.3, Climate Change, and 2.6.4, Renewable Energy and Fossil Fuels, include responses to comments concerning these items.

2.3.4 Consistency with DRB Compact and Other Programs

2.3.4.1 Special Protection Waters

STATEMENT OF CONCERN (SC-72)

Commenters stated:

- Special Protection Waters are those that meet the standards of Chapter 93 of Pennsylvania Code Title 25. Once a protective use is established for a PA surface water, that use must be maintained, and the surface water is not permitted to degrade. Anti-degradation is a concept that has its roots in the federal Clean Water Act and was promulgated by the U.S. Environmental Protection Agency (EPA). The responsibility for meeting the non-degradation standards is already incorporated in Clean Water Act regulations the Commonwealth implements. According to Pennsylvania's Department of Environmental Protection (DEP), over 94 percent of Wayne County streams are designated as Special Protection Waters. This result is from years of dedication and hard work by landowners, farmers, townships, the County and by DEP.

- The entire non-tidal Delaware River is protected by DRBC Special Protection Waters (SPW) anti-degradation regulations due to the exceptional values of the River. The strict regulations adopted by DRBC to protect the water quality of SPW waters requires that the existing high water quality be maintained so that there is "no measurable change" except towards natural conditions.

- To obtain DRBC approval, new discharges to waters classified as SPW must demonstrate "no measurable change" to existing water quality as defined by the regulations for a list of parameters at established water quality control points. The parameters include: alkalinity, hardness, pH, dissolved oxygen, temperature, turbidity, dissolved and suspended solids, nutrient parameters and bacteria. Notably, no "pollutants of concern" are proposed to be added to these parameters by way of the proposed rulemaking. If DRBC wishes to modify the SPW regulations to add more water quality parameters, then DRBC should open the SPW Regulations for revision and comment.

RESPONSE (R-72)

Initially adopted in 1992, and expanded in 1994 and 2008, the Commission's Special Protection Waters ("SPW") program implements "the policy of the Commission that there be no measurable change in existing water quality except toward natural conditions in [interstate] waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values." (Water Code § 3.10.3 A.2). Through stricter reporting requirements and controls on point and non-point discharges, the Commission's SPW program is designed to prevent degradation in interstate streams and rivers where existing water quality is better than the applicable standards require. The Commission has designated the entire 197-mile non-tidal Delaware River from Hancock, N.Y. to Trenton, N.J. as SPW. Notably, three-quarters of this reach has also been included by Congress in the

National Wild and Scenic Rivers System. In addition, 113 miles (57 percent) of the non-tidal Delaware River have also been designated units of the National Park System.

The Commission's SPW program does not examine the effect of individual discharges in isolation, but rather considers the cumulative impacts of disparate pollutant loadings at a series of downstream water quality control points. Under the program, new or expanded pollutant loadings are permitted as long as they do not measurably change water quality at the applicable control point. To administer the program, DRBC relies on ambient monitoring at approximately 60 locations through an informal partnership with the National Park Service (NPS). Computer modeling is used to determine the effluent limits required to ensure no measurable change as the result of a proposed new or expanding discharge.

The Commission's SPW program is administered pursuant to the Delaware River Basin Compact and is distinct from water quality programs of the Pennsylvania Department of Environmental Protection (PADEP) implemented by PADEP pursuant to the Pennsylvania Clean Streams Law and as a delegated program under the federal Clean Water Act. The main stem Delaware River has SPW status only under DRBC's program, not PADEP's, although the Commonwealth has supported DRBC's SPW designations in each instance.

The DRBC does not dispute the commenter's assertion that according to the PADEP and Wayne County Department of Planning, approximately 94 percent of the land area of Wayne County drains to streams that the PADEP has classified as "Special Protection." Notably, 100 percent of the land area within the portion of Wayne County located in the Delaware River Basin drains to streams so classified by the PADEP. All of Wayne County within the Delaware River Basin also falls within the drainage area of DRBC's SPW. The DRBC acknowledges that landowner, local, county and state actions have contributed to the high quality of the non-tidal Delaware River and its tributaries. The DRBC's actions have also played a vital role in this achievement.

2.3.4.2 National Wild and Scenic Rivers Program

Statement of Concern (SC-73)

Commenters stated:

- The Delaware River was designated as a National Wild and Scenic River by Congress because of its outstanding features, irreplaceable resources, exceptional water quality and scenic and recreational value.

- The magnitude of risks and cumulative potential impacts from natural gas development within the DRB are incompatible with the goals of the Wild and Scenic River Management Plan.

RESPONSE (R-73)

Portions of the Delaware River and some of its tributaries have been designated by the Federal Government as parts of the National Wild and Scenic Rivers system.

In 1978, pursuant to the Wild and Scenic Rivers Act (16 U.S.C. §§ 1271-1287) Congress designated the Middle Delaware National Scenic and Recreational River (managed by the Delaware Water Gap National Recreation Area) and Upper Delaware Scenic and Recreational River as both units of the national park system and components of the National Wild and Scenic Rivers System.

In 2000, Congress designated multiple sections and tributaries of the Lower Delaware National Wild and Scenic River (including Tinicum Creek, Tohickon Creek, and Paunacussing Creek) as a partnership river. Then, in 2006, the fourth river in the Delaware River Basin-the Musconetcong National Wild and Scenic River, a tributary to the Delaware-was designated by Congress as a partnership wild and scenic river.

Lands where the NPS provides technical and financial assistance but are neither federally owned nor directly administered by the NPS are referred to as "NPS Affiliated Areas". NPS Affiliated Areas comprise a variety of sites that preserve significant properties outside the National Park System. Some of these have been recognized by Acts of Congress, while others have been designated by the Secretary of the Interior under an appropriate authority (Historic Sites Act of 1935 [16 U.S.C. §§ 461-467], National Wild and Scenic Rivers Act) and include non-NPS administered designated partnership Wild and Scenic Rivers.

Section 10 of the Wild and Scenic Rivers Act requires federal agencies to manage designated rivers in a manner that protects and enhances the free-flowing condition, water quality, and Outstandingly Remarkable Values for which a river was designated. Section 10 directs that primary emphasis be given to protection of a river's scientific and other features. This is an affirmative, anti-degradation and enhancement policy.

Within the Upper Delaware Scenic and Recreational River, the integrity of its ecological communities, presence and size of dwarf wedgemussel populations (federally endangered), and the presence of the full complement of freshwater mussels makes the upper Delaware River exemplary at a regional and national scale. The corridor's pristine resources offer outstanding river recreation in close proximity to the most densely populated region in the United States. The quality of this experience is considered exemplary at a regional scale.

Although the federal government administers the Wild and Scenic program, when Congress created the program in 1968, it envisioned a cooperative system that would rely on the combined efforts of state, local, and federal governments, along with individual citizens and non-governmental organizations. The system was intended to be flexible enough to provide a means for communities to protect their rivers in a way that is sensitive to the needs and concerns of the people who live, work, and recreate along the rivers.

The Commission incorporated the Upper Delaware Scenic and Recreational River into the Comprehensive Plan on July 26, 1978 by approving Docket No. D-1978-051 CP. The docket approval included the provision that the final management plan, a federal requirement, "must be submitted to and approved by the Commission under Section 3.8 of the Compact." On November 4, 1987, the NPS submitted an application to the Commission for the inclusion of the *Upper Delaware Scenic and Recreational River Management Plan* (U-MP, or Management Plan) in the DRBC Comprehensive Plan. On March 23, 1988 the Commission voted to revise Docket No. 1978-051 CP, the first Commission approval for the UDS&RR. The Revisions supplemented the initial (1978) description of the project, established conditions of DRBC's non-voting participation in the proposed Upper Delaware Council (UDC), addressed the revised boundaries of the region, and reaffirmed the inclusion of the UDS&RR Project in the Comprehensive Plan. The Docket endorses "the intent of the Management Plan", and stated that the Commission retains its authority over any proposed project subject to review under Section 3.8 of the Compact and the Commission's Administrative Manual, allowing that while conducting such reviews, it would consider the impact on all areas within the boundary of the UDS&RR area to determine impairment or conflicts with the Comprehensive Plan.

The Commission incorporated the Delaware Water Gap Natural Recreation Area General Management Plan into the Comprehensive Plan on October 28, 1987 by approving Docket No. D-1987-065. The GMP was found to be consistent with the DRBC Comprehensive Plan and all DWGNRA present or future publicly owned areas and facilities were added to the DRBC Comprehensive Plan.

The Commission's water quality programs – in particular, its Special Protection Waters program described above – protects the Delaware River's Wild and Scenic designations by protecting water quality, one of the natural resource values that served as a basis for these congressional Wild and Scenic designations. The Commission's rule will protect the Basin's Wild and Scenic rivers from the water resource impacts associated with high volume hydraulic fracturing and related activities by prohibiting such activities within the Basin.

2.3.4.3 Flexible Flow Management Program

Statement of Concern (SC-74)

Commenters stated:

- If the proposed regulations are going to allow significant bodies of water to be removed from the river, this is going to have incredible implications for the flexible flow management plan and New York City's operation of the upper Delaware Basin reservoirs.
- It is counterproductive to the FFMP to allow water exports that will impact flows, groundwater reserves, and stream stability by permitting further depletive uses.

Response (R-74)

After carefully considering the public comments received on the November 2017 draft rules, the Commission is withdrawing from consideration the provisions of its draft rule relating to the exportation of water from the Delaware River Basin for hydraulic fracturing and related activities (Section 440.4). The topic of water exportation will be addressed through one or more separate Commission actions. Because the Final Regulation prohibits HVHF in the Basin, no withdrawals will take place to supply water for in-Basin HVHF activities.

2.3.4.4 Delaware River Basin Compact

STATEMENT OF CONCERN (SC-75)

Numerous commenters stated that anything short of a complete ban on drilling and fracking related activity—including water-related withdrawal and wastewater importation, treatment and disposal—would be a dereliction of DRBC's stated vision and leadership.

RESPONSE (R-75)

After careful review of all comments submitted on the draft regulation, the Commission is finalizing its proposed prohibition on HVHF within the Basin (18 C.F.R. § 440.3). The Commission is also withdrawing proposed Sections 440.4 and 440.5 of the draft rule, concerning exportations of water for hydraulic fracturing of oil and natural gas wells and the importation, treatment and disposal of produced water from such wells. The topics of water exportation and wastewater importation will be addressed through one or more separate Commission actions.

STATEMENT OF CONCERN (SC-76)

Commenters stated:

- The Delaware River Basin Commission is not heeding its charges under the Compact "to remove causes of present and future controversy" and "provide for cooperative planning." Fracking does not reduce controversy.

- The DRBC, in its decision to unilaterally impose these regulations by arbitrary fiat, is thwarting its responsibility to conduct "cooperative planning" with member states, as required under the Compact.

RESPONSE (R-76)

The Delaware River Basin Compact, from which one of the commenters quotes, states:

> In general, the purposes of this compact are to promote interstate comity; to remove causes of present and future controversy; to make secure and protect present developments within the states; to encourage and provide for the planning, conservation, utilization, development, management and control of the water resources of the Basin; to provide for cooperative planning and action by the signatory parties with respect to such water resources; and to apply the principle of equal and uniform treatment to all water users who are similarly situated and to all users of related facilities, without regard to established political boundaries.

(Compact, § 1.3(e)).

The Commission's regulation prohibiting HVHF is adopted by vote of a majority of the member Commissioners on behalf of the signatory parties to the Compact, i.e., the Delaware River Basin states and federal government after an extensive public process, careful evaluation of the available science in light of DRBC policies, and extended consideration by the five Commissioners—four governors and on behalf of the federal government, the Commander, North Atlantic Division, U.S. Army Corps of Engineers, assisted by DRBC staff and the technical staff of the Commission's member agencies. In the view of the Commission this action achieves the procedural and substantive purposes set forth in the referenced section of the Compact.

Statement of Concern (SC-77)

One of the core purposes of the Compact is to apply the principle of equal and uniform treatment of all water users without regard for established political values. The Commission's proposed actions are anything but equal or uniform and its outcome should not be allowed to prevail.

Response (R-77)

The Compact's stated purposes include in relevant part, "to apply the principle of equal and uniform treatment to all water users *who are similarly situated* and to all users of related facilities, without regard to established political *boundaries.*" (Compact, § 1.3(e) (emphasis added)). In establishing the Commission's geographic jurisdiction, the Compact provides, "The Commission shall have, exercise and discharge its functions, powers and duties within the limits of the basin, except that it may in its discretion act outside the basin whenever such action may be necessary or convenient to effectuate its powers or duties within the basin . . . ." (Compact, § 2.7). Because the Commission's rulemaking applies equally and uniformly to all similarly situated water users within the DRB, it is consistent with the core principle cited by the commenter, as well as with the authority conferred on the Commission by the Compact.

Objections to disparate treatment between water users within the Delaware River Basin and water users outside the Basin are addressed in the section of this Comment and Response Document that discusses the doctrine of equal protection under the United States Constitution. *See* Section 2.6.10 (Other Legal Comments). In that section, the Commission explains that the Equal Protection Clause requires a rational basis for a governmental classification. The Commission has not asserted jurisdiction over HVHF activities in any location other than the Delaware River Basin, and thus has not classified out-of-Basin activities at all, let alone classified them differently from in-Basin activities. An equal protection issue does not arise where different regulators with separate jurisdictional authorities take different regulatory approaches. DRBC notes, however, that certain geological characteristics and differences in water needs and uses distinguish the Basin from other locations.

Statement of Concern (SC-78)

AXPC (American Exploration and Production Council) believes that the rule proposal would conflict with the Commission's 2001 Comprehensive Plan. As detailed in the Introduction, specifically in Section D, the Comprehensive Plan provides, ". . . a flexible, growing and evolving general framework for the orderly development of the water and related resources of the Basin." We assert that this statement is intended to embrace innovation and technological advancement by the various water users within the DRBC's jurisdiction and reflect such achievements in its regulations. A ban on any activity within the Basin is obviously outside the realm of a flexible, evolving framework.

Response (R-78)

As the Compact recognizes, "The water resources of the Basin are functionally interrelated, and the uses of these resources are interdependent." (Compact, § 1.3(e)). The Commission has determined that the use of vast quantities of water over large portions of the Basin for and during high volume hydraulic fracturing and related activities risks permanently foreclosing or impairing other uses of the Basin's waters that are protected by the Comprehensive Plan. These protected uses include public water supply and commercial and industrial activities that also require large quantities of high-quality water. In order to effectuate the Comprehensive Plan, the Commission cannot responsibly allow a new industry to consume, degrade, foreclose all future use of, or place at permanent risk, the resource the Commission is charged with managing for the benefit of more than 13 million users. If scientific innovation and technological advances in the future demonstrate that high volume hydraulic fracturing can be performed without the adverse impacts on water resources that have been demonstrated to date, a future group of governors and federal representatives, acting in their capacity as DRBC Commissioners, may exercise their discretion to reconsider this question.

Statement of Concern (SC-79)

A number of commenters recommended that DRBC perform a cumulative impact analysis. The following are representative of their comments:

1. A buildout of this size will bring enormous impacts on air, land, and water and the communities proximate to these activities. Based on industry projections and current rates of consumption, the cumulative impact of the O&G buildout would require 583 billion gallons of fresh water depleted from the system.

2. It is unclear whether language in section 2.30.4 (F and G) of the Commission's Water Code, requiring applicants to describe the "relationship" of proposed projects to all other diversions and other DRBC actions, is intended to capture the cumulative impacts of proposed projects. I recommend that this language be clarified to more clearly to require cumulative impact analysis, as defined in the DRBC's *Administrative Manual – Part III Water Quality Regulations*, and that this analysis be required for both the export of water and importation of wastewater associated with hydraulic fracturing.

3. We urge the DRBC to carefully consider the sensitivity of headwaters resource areas to water withdrawals and the potential cumulative impacts to surface and groundwater resources of this consumptive use.

4. An analysis of the cumulative impacts of consumptive uses in the Basin—including the water withdrawals and wastewater disposal that would be allowed by the draft regulations—is necessary to determine appropriate limitations on such withdrawals. In order to address potential adverse impacts associated with aggregated consumptive withdrawals, DRBC should use a cumulative impact analysis to establish standard permit terms which would specify under what river flow conditions withdrawals or wastewater discharges would be temporarily halted.

5. Proper management of the withdrawal through flow analysis, cumulative impact studies, pass-by flow determinations, in-stream flow need assessments and long-range planning are what is needed to protect the resources of the Basin.

6. DRBC's duties under the Comprehensive Plan require the Commission to consider whether and where an activity, as a whole—such as unconventional gas development—fits in the Basin, and its cumulative impacts.

7. The Commission recognized the potential cumulative impacts of hydraulic fracturing activities on the water resources of the Basin to be so significant that the Commission applied for federal funding for a cumulative impact study. The U.S. House of Representatives Appropriations Committee Subcommittee on Interior, Environment, and Related Agencies approved $1 million for the U.S. Geological Survey and the Commission to conduct that study, but due to the lack of needed action on the federal budget, these funds were not granted in the Congressional session. The foresight the Commission has shown in seeking these funds is exemplary. We are in full support of this effort and have continued to seek funding sources for the Commission ourselves.

8. In our opinion, a cumulative impact analysis of the potential effects of natural gas development on the Basin's resources is essential to developing appropriate rules that will fulfill the DRBC's mandates.

Response (R-79)

The Commission carefully examined the actual and potential water resource impacts of HVHF and related activities through a comprehensive review of the literature, including an analysis of cumulative effects performed by the State of New York in its Supplemental Generic Environmental Impact Statement (NYSDEC, 2015), among others. In addition to this comprehensive literature review, the Commission undertook an extensive public process and deliberated at length on the matter before determining that a prohibition on HVHF activities to eliminate adverse impacts on the Basin's water resources is required. The Commission believes it has thus met its obligations under the Compact and implementing regulations to determine the potential effects of HVHF and related activities on the Basin's water resources. Notably, in Section 2.6.10 (Other Legal Comments) the Commission explains that it is not a federal agency subject to the National Environmental Policy Act ("NEPA"), and thus is not obliged to prepare an environmental impact statement under that law.

With respect to the comments set forth above, numbers 2, 6, and 8 suggest that DRBC is required or should be required by the Compact and its implementing regulations to perform a cumulative impact analysis in connection with its proposed rulemaking. In addition to the statement immediately above, the Commission notes that the term "cumulative impact" appears just once in DRBC's regulations, in Section 3.10.3 A.2.a.11) of the Delaware River Basin Water Code and the Water Quality Regulations. There, it refers specifically to the effect of proposed new or expanding point source discharges on water quality in the Commission's Special Protection Waters (SPW), as measured at specific control points established by the regulations. Although the Commission may give, and as noted above here has given, consideration to the totality of expected impacts from HVHF if it were permitted in the DRB, the Commission has discretion to determine the circumstances under which it will examine cumulative impacts.

Sections 2.30.4 F. and G. of the Water Code, cited in the comment numbered 2 above, relate solely to water imports and exports. The comments numbered 1, 3 and 4 above address the potential cumulative impacts of water withdrawals from the Basin or from sub-watersheds of the Basin, and consumptive uses of the Basin's waters. Notably, the exportation and consumptive use of waters raise questions involving the timing and location of withdrawals, matters that the Commission does routinely address on a cumulative basis when it evaluates proposed withdrawals and diversions of surface and ground water. Notably, however, draft Sections 440.4 and 440.5 of the proposed rule relating to these subject matters are being withdrawn by the Commission from consideration and will be addressed through separate Commission action.

The comment numbered 5 by the Marcellus Shale Coalition, in reference to surface water withdrawals exclusively, suggests that common management tools exist and are effectively employed by the Susquehanna River Basin Commission to protect the Basin's resources. However, the commenter's notion of "cumulative effect" in this context does not address the water resource risks posed by high volume hydraulic fracturing that are not comprehensively managed by the SRBC. These include the risks discussed in Sections 2.3.2.2 through 2.3.2.5 of this Comment and Response Document.

In the comment numbered 7 above, the Delaware Riverkeeper Network (DRN) mentions a 2011 study proposal by the DRBC that was never funded and suggests that DRN has continued to seek funds to support DRBC's 2011 proposal. The Commission is unaware of such efforts. Regardless, in the view of the Commission, our comprehensive literature review, extensive public process and lengthy deliberation on the matter of protecting the Basin's water resources from the actual and potential adverse impacts of HVHF and related activities consistent with Commission policies fulfill the Commission's responsibilities under the Delaware River Basin Compact to make an informed and lawful decision in this matter.

2.4 Rule Section 401.35 – Classification of Projects for Review Under Section 3.8 of the Compact

STATEMENT OF CONCERN (SC-80)

A commenter offered the following objections to DRBC's proposal to amend its threshold for the review of activities affecting wetlands:

- All alterations to wetlands or marshes, including areas less than 25 acres, and regardless of whether a state or a federal level review and permit system is in effect, should be subject to Commission review and action. There is no justification for the Commission's current review threshold of 25 acres.

- DRBC [has] more local and immediate information, data, and knowledge of wetlands than the state or federal agencies. DRBC has the potential for more comprehensive and accurate assessment of proposed disturbances in wetlands and marshes within the Basin than state or federal agencies and therefore supports DRBC review of these activities.

RESPONSE (R-80)

The Delaware Riverkeeper Network (DRN) offered comments to the effect of those set forth above regarding the Commission's proposal to revise 18 C.F.R. § 401.35(a)(15), establishing the circumstances under which a project involving draining, filling or otherwise altering marshes or wetlands "will be deemed not to have a substantial effect on the water resources of the Basin and is not required to be submitted under Section 3.8 of the Compact" (18 C.F.R. § 401.35(a)).

The Commission's 25-acre threshold for the review of projects altering wetlands has been in effect since its adoption by Resolution No. 1978-10 on June 28, 1978. Because federal and state review and permit systems for wetland disturbances have long been in place throughout the Basin, the Commission has reviewed very few projects affecting wetlands since that time. Rather, adhering to the directive of Section 1.5 of the Compact that it "utilize the functions, powers and duties of existing offices of government … for the purpose of this compact to the fullest extent it finds feasible and advantageous[,]" the Commission has consistently relied upon the wetlands review and permitting programs and expertise of its member state and federal agencies.

The amendments to 401.35(a) included in the Commission's Notice of Proposed Rulemaking on November 30, 2017 removed from the text of paragraph 401.35(a)(15) certain express exceptions to the 25-acre threshold. In few of the global exception retained by paragraph 401.35(c) as amended, these wetlands-specific exceptions are redundant. With proposed amendments, section 401.35(c) provides, "Regardless of whether expressly excluded from review by paragraph (a) of this section, any project or class of projects that in the view of the Commission could have a substantial effect on the water resources of the Basin may, upon special notice to the project sponsor or landowner, be subject to the requirement for review under section 3.8 of the Compact." Accordingly, as under the original language of paragraph 401.35(a)(15), the Commission may review wetlands disturbances of fewer than 25 acres if it determines that such review is appropriate under the circumstances of a particular project proposal. In the view of the Commission, no change to the 25-acre threshold is warranted, and none was or is now proposed.

STATEMENT OF CONCERN (SC-81)

A commenter suggested that the Commission modify its proposed amendment of 18 C.F.R. § 401.35(a)(18) to make the importation into the Basin of wastewater of any kind in any quantity subject to the Commission's review under Section 3.8 of the Compact.

RESPONSE (R-81)

In view of the water quality standards and effluent limits implemented by Basin state agencies and the DRBC, the Commission historically has deemed importations of wastewater at less than a daily average rate of 50,000 gallons to have no substantial effect on the Basin's water resources. *See* 18 C.F.R. § 401.35(a)(18). Since 2009, however, the Commission has in many instances conditioned its approvals of wastewater discharge projects on a requirement that no importation, treatment and/or discharge of hydraulic fracturing wastewater may be undertaken by the docket holder without the Commission's prior review and approval.

In part in view of the comments received on the Commission's draft rules proposed at 18 C.F.R. § 440.2, 440.4 and 440.5 concerning transfers of water and/or wastewater into and out of the Basin to support hydraulic fracturing for the extraction of natural gas from shales, the Commission is withdrawing proposed sections 440.4 and 440.5 and the related definitions at section 440.2, along with references to these definitions that it proposed adding to 18 C.F.R. §§ 401.35(a) and (b) regarding the classification of projects for review under Section 3.8 of the Compact. The Commission will update its regulations concerning transfers of water and wastewater into and out of the Basin under a separate rulemaking.

Statement of Concern (SC-82)

A commenter suggested that the Commission revise 18 C.F.R. § 401.35(b)(14) to read: "Leachate treatment and disposal projects associated with landfills and solid waste disposal facilities in the Basin, landfills and solid waste disposal facilities affecting the water resources of the Basin."

Response (R-82)

The language at 18 C.F.R. § 401.35(b)(14) is intended to be read in combination with section 401.35(a)(14), to which no change was proposed. The latter provides that landfill projects are deemed not to have a substantial effect on the water resources of the Basin and thus are not subject to Section 3.8 review under the Compact,

> *unless* no state-level review and permit system is in effect; broad regional consequences are anticipated; or the standards or criteria used in state level review are not adequate to protect the water of the Basin for the purposes prescribed in the Comprehensive Plan[.]

(Emphasis added).

In accordance with the above provision, under certain circumstances landfill projects having a substantial effect on the Basin's water resources may be reviewed under Section 3.8. However, because effective state permit and review systems are in place for landfills, the Commission typically does not review them, and the proposed change was intended to reflect this. Because the proposed change appears to have created confusion rather than eliminating it, the change will not be adopted and instead is being withdrawn.

Statement of Concern (SC-83)

The Commission received comments such as those below regarding the effect on 18 C.F.R. § 401.35(b)(15) (the Commission's existing provision for the review of leachate treatment and disposal projects) of amendments to that provision (re-numbered as § 401.35(b)(14) in the proposed rule) of two entirely new proposed provisions: § 440.2, defining the terms "produced water," "centralized waste treatment facility" and "CWT wastewater," and § 401.35(b)(18), containing those new terms.

- The DRBC's proposed new section 18 C.F.R. § 401.35(b)(18) appears to confuse rather than clarify the application of the DRBC's water quality criteria to leachate. The concept of the

Centralized Waste Treatment Facility could be interpreted to address the receipt of leachate at a facility. The DRBC should clarify the intent of this provision.

- The DRBC has proposed a revised provision concerning leachate treatment and solid waste disposal facilities at § 401.35(b)(14) (formerly (b)(15)). The DRBC proposes changes to the existing language, which originally related to landfill and solid waste facilities that could impact the DRB's water quality. The new provision can be read to apply to any leachate treatment project located within the Delaware River Basin and associated with a landfill or solid waste disposal facility in the DRB, or potentially to a leachate treatment facility located within the DRB that treats leachate from any landfill, whether within the Delaware River Basin or not. The specific concern is that "leachate treatment projects" is not a defined term.

RESPONSE (R-83)

The DRBC intends to continue to review projects for the discharge of treated leachate when such discharges meet the thresholds for review established by 18 C.F.R. §§ 401.35(a)(5) and (b)(8), concerning the treatment and discharge of industrial wastewater. As discussed above and elsewhere in this response to comments, the proposed definition of "centralized waste treatment facility" in new § 440.2 and all references to this definition in §§ 401.35(a) and (b) are being withdrawn, as are §§ 440.4 and 440.5 in their entirety. The topics of water exportation and wastewater importation will be addressed through one or more separate Commission actions. Facilities for the treatment and discharge of leachate will continue to be regulated by the DRBC under existing thresholds for the review of facilities for the treatment and discharge of industrial wastewater or domestic wastewater comingled with industrial wastewater.

2.5 Rule Section 401.43 – Regulatory Program Fees

The Commission received no comments on its proposed amendments to 18 C.F.R. § 401.43.

Consistent with the Commission's withdrawal of proposed § 440.5 (Produced water), the proposed amendments to § 401.35 to establish fees for "wastewater treatability reviews" are not included in the final rules.

2.6 Other Comments Related to the Rules

2.6.1 Public Health

STATEMENT OF CONCERN (SC-84)

Numerous commenters expressed concerns about the substances used and generated during unconventional oil and gas development, their toxicity, the pathways of exposure, and ultimately, the potential for adverse public health effects resulting from exposure to these substances.

Other commenters suggested that the Commission's sources regarding adverse health effects associated with HVHF are flawed, politically motivated, and lacking in scientific validity. Some asserted that the more reliable studies and reports conclude there is no discernible negative public health impact resulting from hydraulic fracturing or that public health conditions have improved as a result of HVHF.

Commenters including private citizens, environmental advocacy groups, municipalities within the Basin, and the New York State Office of the Attorney General, who expressed support for Section 440.3 of the draft rule banning high volume hydraulic fracturing within the Basin, offered comments along the lines of those quoted or paraphrased below:

- Numerous published studies (around 1,300) show that a variety of activities associated with hydraulic fracturing and extraction of natural gas threaten drinking water and put public health at risk.

- A compendium published by Concerned Health Professionals of New York and Physicians for Social Responsibility stated that 685 peer-reviewed papers examining gas drilling and/or hydraulic fracturing were reviewed, and an overwhelming majority found evidence of or potential adverse impacts on water, air, and human health.

- "There is no evidence that fracking can operate without threatening public health directly or without imperiling climate stability upon which public health depends." (CHPNY and PSR, 2018, p. 266).

- The environmental risks (air and water pollution) from gas wells and the associated threats to public health and safety are disproportionately borne by those who reside, work, or go to school in, or otherwise frequent areas in proximity (within approximately two (2) miles) of natural gas well pads. Studies show that those residing closest to well pads have greater exposure and are more likely to develop disease and health problems.

- After exhaustive study, the State of New York prohibited fracking based on an environmental and public health analysis. The New York State Department of Health concluded that the overall weight of the evidence demonstrated the likelihood that adverse health outcomes and environmental impacts from fracking could not be prevented, leading to a statewide ban on high volume hydraulic fracturing. The State of Maryland permanently banned fracking after two years of study, based on the potential for adverse public health and environmental impacts.

- As fracking has increased nationwide, the negative health impacts of this practice are becoming apparent. Fracking uses large amounts of many toxic chemicals and produces large amounts of toxic and radioactive wastes and these have impacted ground water and aquifers, and thus the health of residents. In order to protect the health of the residents of the Delaware River Basin, fracking must be banned.

- Historically, humans have embraced new technologies with little or no evidence as to the deleterious effects that could result, only to learn later about the risks and human costs and how they can be eliminated or minimized. We cannot be too careful with a water source which has the potential to affect the health of so many individuals and communities.

The following paraphrased statements are representative of those expressing opposition to draft Section 440.3 of the rule (which prohibits high volume hydraulic fracturing within the Basin) and to assertions that hydraulic fracturing may have adverse impacts on human health:

- Public health conditions have improved as a result of the economic benefits realized from Marcellus Shale resource development/hydraulic fracturing, as indicated by:

  - Reduced mortality rates in the six (6) Pennsylvania counties where fracking operations are most prevalent.

  - Asthma rates and hospitalizations and mortality rates have fallen following extensive shale development.

- Research conducted by epidemiologists and public health experts around the world proves that there is no rational public health basis for prohibiting natural gas development in the Basin. The documented public health *benefits* of natural gas development, including reduced mortality rates, can be tied directly to the economic benefits realized from Marcellus Shale resource extraction.

- In the Susquehanna River Basin, many of the studies being used as evidence of harm in fact show no causation and rely on assumptions without any actual samples. Contrary to the assertions made by the authors of these studies, asthma rates and hospitalizations have fallen.

RESPONSE (R-84)

Research that strives to better understand the relationship between high volume hydraulic fracturing (HVHF) activities and public health is ongoing. The Commission finds that the science on this very important topic continues to emerge and there is much more to learn than is currently known. As regards the comment suggesting that HVHF has not been identified as the direct cause of a specific adverse public health outcome, it is critical to note much of the published literature on the subject points to associative relationships between the environmental threats posed by HVHF and public health. This is not a limitation of the current body of knowledge on this subject nor is it unique to HVHF compared to other public health risks; rather, it is consistent with epidemiologic research, generally, in that such studies allow for the direct observation of association rather than cause.

The protection of public health is an inherent benefit of the Commission's water resource management and protection programs. In accordance with Section 5.2 of the Compact, protection of public health from existing or future pollution of water resources is a factor the Commission may and did consider in connection with adoption of the Final Regulation. For the reasons discussed in this Section and elsewhere in the Comment and Response Document, the risks to public health support the Final Regulation. Nevertheless, the DRBC is primarily an interstate and federal water resource management agency, not a public health agency. In many instances, commenters on the Commission's draft regulations addressed public health matters that are not, or may not be, water resource-related. While the Commission acknowledges these broader concerns, our focus continues to be the coordinated management of shared water resources consistent with the Commission's Comprehensive Plan for the immediate and long-range development and uses of the water resources of the Basin. *See,* Compact § 3.2(a).

In considering the comments submitted on the subject of public health outcomes associated with HVHF, the Commission and its staff have reviewed the scientific literature on this subject. A consistent theme that emerges from the research on this topic is that HVHF on a broad scale is relatively young, particularly in Pennsylvania. Although some known toxic and persistent chemicals and other substances are used and/or brought to the surface during HVHF activities, published information does not exist on the biodegradability and toxicity of many of the more than 1,000 chemicals used in and/or generated by hydraulic fracturing projects (Stringfellow *et al.,* 2014). More importantly for considerations related to public health, toxicity and associated human health effect values have been established for only a small subset (~11 percent) of these substances, according to the EPA (U.S. EPA, 2016a, p. 9-1). Despite the paucity of data, the known health effects associated with chronic oral exposure to some of these chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity (U.S. EPA, 2016a, p. 9-1). The limitations of the then-current science were acknowledged by the New York State Department of Health in 2014 when it reported:

> Comprehensive, long-term studies, and in particular longitudinal studies, that could contribute to the understanding of those relationships are either not yet completed or have yet to be initiated.

(NYSDOH, 2014, p. 11). In a similar vein, the EPA in its 2016 report on the impacts of the hydraulic fracturing water cycle on drinking water resources stated:

> Although none of these studies demonstrate a direct effect of hydraulic fracturing activity on human health, and none of the epidemiological studies provided measures of individual or population level exposures or differentiated between drinking water contamination and other potential routes of exposure (e.g., air pollution), all are suggestive of a relationship between unconventional oil and gas development and adverse health outcomes.

(U.S. EPA, 2016a, p. 9-7).

Pointing to evidence of a correlation between proximity to hydraulic fracturing activity and increased public health risks, Xu *et al.* report in 2019:

> Although monitoring data on HF-related chemicals in water resources are not widely available, the rapid growth in the application of HF has raised great concerns about the potential impacts of HF-related water contamination on human health. It is increasingly common that the sites of HF mostly are located near residency and drinking water resources. For example, more than 9.4 million population lived within one mile of a HF well and approximately 6,800 sources of drinking water for public water systems were located within one mile of at least one HF well between 2000 and 2013. These facts increase the chance of potentially exposing people to the HF-related water contamination. Existing studies have reported that people living in close proximity to shale gas facilities have increased risks of health problems such as adverse pregnancy outcomes, dermal and respiratory conditions, and psychological

> change, yet the potential carcinogenic effects of HF-related chemicals have rarely been studied.

(Xu *et al.,* 2019).

The totality of the risks, vulnerabilities, impacts and uncertainties discussed throughout this comment and response document support the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. Inherent in the protection of those uses, which include drinking water, is the protection of public health and safety.

New York State Department of Health (NYSDOH) Public Health Review of High volume Hydraulic Fracturing

The New York State Department of Environmental Conservation in 2012 requested that the New York State Department of Health review and assess the analysis of public health impacts contained in the former's Draft Supplemental Generic Environmental Impact Statement ("SGEIS") on HVHF. In conducting its review, the NYSDOH evaluated whether the available scientific and technical information provided an adequate basis for understanding the likelihood and magnitude of the risk of adverse public health impacts from HVHF activities in New York State. The NYSDOH reviewed, among other things, "how HVHF activities could result in human exposure to: (i) contaminants in air or water; [and] (ii) naturally occurring radiological materials that result from HVHF activities . . . . DOH also reviewed whether those exposures may result in adverse public health outcomes." (NYSDOH, 2014, pp. 2-3). The NYSDOH's initial 2014 assessment was expanded:

> to consider, more broadly, the current state of science regarding HVHF and public health risks. This required an evaluation of the emerging scientific information on environmental public health and community health effects. This also required an analysis of whether such information was sufficient to determine the extent of potential public health impact of HVHF activities in NYS and whether existing mitigation measures implemented in other states are effectively reducing the risk for adverse public health impacts.

(*Id.,* p. 3.). As a result of this expanded review, the NYSDOH concluded that:

> the overall weight of the evidence from the cumulative body of information contained in this Public Health Review demonstrates that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health. Until the science provides sufficient information to determine the level of risk to public health from HVHF to all New Yorkers and whether the risks can be

> adequately managed, NYSDOH recommends that HVHF should not proceed in New York State.

Id., p. 2; *also see, id.,* pp. 11-12.

Additional discussion of NYSDOH's report is contained in Section 2.3.1.2, New York State Reports, of this Comment and Response Document.

New York State Final Supplemental General Environmental Impact Statement (Final SGEIS)

The comprehensive analysis that led to New York State's determination to prohibit HVHF began when the state saw the rapid expansion of hydraulic fracturing in the Marcellus and Utica Shale formations and recognized the potential for natural gas development to spread rapidly across a large area of south-central New York before its potential impacts on public health and the environment were fully understood. In response, the NYSDEC undertook an exhaustive assessment of the potential environmental impacts associated with HVHF. NYSDEC's analysis included consideration of a range of regulatory standards and mitigation measures that might be implemented to reduce potential adverse impacts of HVHF on the environment and public health. As discussed above, NYSDEC consulted and coordinated with NYSDOH in this undertaking. The decision to prohibit HVHF within New York was made in part on the basis of the risks and significant uncertainties reported in scientific and medical studies and other literature, in the interest of protecting public health, safety and the environment. A more thorough discussion of New York State's evaluation and decision-making on HVHF is included in Section 2.3.1.2, New York State Reports.

U.S. Environmental Protection Agency Hydraulic Fracturing Impacts on Drinking Water Resources Study

EPA has acknowledged that its 2016 report does not constitute a human health risk assessment, as EPA lacked the information required to fully characterize exposure and risk. However, Chapter 9, "Identification and Hazard Evaluation of Chemicals across the Hydraulic Fracturing Water Cycle," of the agency's 2016 study on HVHF impacts to drinking water resources provides an overview of identified hazards and a dose-response assessment for chemicals used in HVHF (U.S. EPA, 2016a, p. 9-4). One of the central findings of the chapter follows:

> Overall, while combined evidence suggests hydraulic fracturing has the potential to impact human health via contamination of drinking water resources, the actual public health impacts are not well understood and not well documented. Available information indicates there are many chemicals within the hydraulic fracturing water cycle that are known to be hazardous to human health, as well as hundreds of chemicals for which toxicological data is limited or unavailable.

(U.S. EPA, 2016a, p. 9-8). EPA identified 1,606 chemicals associated with the hydraulic fracturing water cycle, including 1,084 used in hydraulic fracturing fluids and 599 more detected in produced water (*see id.,* p. 9-1). EPA also identified chronic oral toxicity values for 98 of the 1,084 chemicals reportedly used in hydraulic fracturing fluids between 2005 and 2013 (*see id.*, p. 9-16).[39] Despite the incomplete research on this topic, EPA found that the human health effects associated with chronic oral exposure to many of these chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity (*see id.,* p. 9-1). EPA further concluded that "the majority of chemicals associated with hydraulic fracturing activity have not undergone significant toxicological assessment" (*id.,* p. 9-22).

In its 2016 report, EPA listed several studies that in its view highlighted an increasing potential for significant public health and environmental impacts based on the increase in hydraulic fracturing operations: Goldstein *et al*. (2014), Finkel *et al*. (2013), Korfmacher *et al*. (2013), and Weinhold (2012). (*Id.,* p. 9-6). Other studies that EPA identified as supporting an association between HVHF and adverse public health effects, and their findings, in brief, include:

- An epidemiological study in Colorado demonstrated that residential proximity of pregnant mothers to natural gas wells is associated with an increased incidence of congenital heart defects, and, to a lesser extent, neural tube malformations (McKenzie *et al.,* 2014).

- A similar study in Pennsylvania found pregnant mothers living closer to unconventional natural gas wells were more likely to have infants that were small for gestational age, with lower birth weights compared to infants from mothers living farther from wells (Stacy *et al.,* 2015).

- Residential proximity to natural gas wells in the Marcellus Shale is associated with an increase in the number of self-reported health symptoms, particularly upper respiratory and dermal symptoms (Rabinowitz *et al.*, 2015), chronic rhinosinusitis, migraine headache, and fatigue symptoms (Tustin *et al.,* 2016).

- Laboratory studies have found that endocrine disrupting activity measured using *in vitro* bioassays may be elevated in surface and groundwater at known hydraulic fracturing spill sites (Kassotis *et al.,* 2014) and in surface water downstream from a hydraulic fracturing wastewater injection facility (Kassotis *et al.,* 2016).

See, U.S. EPA, 2016a, pp. 9-6 – 9-7. Although EPA acknowledged that these studies did not differentiate between drinking water contamination and other potential routes of exposure and did not establish a direct link between hydraulic fracturing activity and human health outcomes, all in EPA's view suggested a relationship between high volume hydraulic fracturing and adverse health outcomes.

For a more detailed discussion of the impacts of HVHF on drinking water, see the response to comments related specifically to drinking water at Section 2.3.3.1, Drinking Water Supplies. Further

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[39] EPA warns that the chemical list should not be considered complete; in its analysis of disclosures submitted to the FracFocus 1.0 database, the agency was able to assign standardized chemical names to only 65% of ingredient records because the remainder did not have valid Chemical Abstracts Service Registration Numbers ("CASRNs") and were thus excluded from EPA's analysis. (*See,* U.S. EPA, 2016a, p. 9-10).

information on the relationship between HVHF chemical toxicity and potential human health outcomes is provided in Section 2.3.2.2, Pollution from Spills.

Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking, 6th Edition, June 2019 (CHPNY and PSR, 2019)[40] ("Compendium")[41]

DRBC received numerous comments referencing the Compendium (or prior editions of the Compendium) as a source of reported public health impacts related to hydraulic fracturing. According to its preface, the Compendium is comprised of:

> collected and compiled findings from three sources: articles from peer-reviewed medical or scientific journals; investigative reports by journalists; and reports from, or commissioned by, government agencies. Peer-reviewed articles were identified through databases such as PubMed and Web of Science, and from within the PSE Healthy Energy database.

(CHPNY and PSR, 2019, p. 4).

The Compendium is described as "generally a voluntary" effort with no dedicated funding source, written "utilizing the experience and expertise of numerous health professionals and scientists . . . ." (*Id.*, p. 4). Its table of contents lists the following sections, each of which consists of an editorial summary and a series of abstracts:

- Air pollution
- Water contamination
- Inherent engineering problems that worsen with time
- Radioactive releases
- Occupational health and safety hazards
- Public health effects, measured directly
- Noise pollution, light pollution, and stress
- Earthquakes and seismic activity
- Abandoned and active wells as pathways for gas and fluid migration
- Flood risks
- Threats to agriculture, soil quality, and forests
- Threats to the climate system
- Threats from fracking infrastructure

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[40] Concerned Health Professionals of New York ("CHPNY") "is an initiative by health professionals, scientists, and medical organizations for raising science-based concerns about the impacts of fracking on public health and safety." (CHPNY and PSR, 2019, p. 2). Physicians for Social Responsibility ("PSR") "uses medical and public health expertise to educate and advocate on urgent issues that threaten human health and survival, with the goals of reversing the trajectory towards climate change, protecting the public and the environment from toxic chemicals, and addressing the health consequences of fossil fuels." (*Id.*).

[41] The Compendium is described by its editors as "a fully referenced compilation of evidence outlining the risks and harms of fracking" and a "public, open-access document that is published by and housed on the websites of [CHPNY] (www.concernedhealthny.org) and [PSR] (www.psr.org)." (*Id.*).

The studies abstracted by the Compendium that relate directly to water resources are discussed as appropriate in other sections of this Comment and Response Document.

Studies abstracted in a section of the Compendium titled, "Public health effects, measured directly" point to a variety of potential pathways of exposure, including water resource contamination. In this section, the editors describe the state of understanding of the human health effects of HVHF as follows:

> By several measures, evidence for fracking-related health problems has emerged across the United States and Canada. Studies of birth outcomes in regions of intensive unconventional oil and gas extraction continue to point to reproductive risks, including low birth weight and preterm births. In Oklahoma and Colorado, birth defects were elevated among infants whose mothers lived near drilling and fracking sites while pregnant.
>
> As shown by multiple studies in Pennsylvania, as the number of gas wells increase in a community, so do rates of hospitalization, and community members experience sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, wheezing, and nausea. Also, in Pennsylvania, hospitalizations for pneumonia among the elderly are elevated in areas of fracking activity, and one study found significantly elevated rates of bladder and thyroid cancers. In Colorado, children and young adults with leukemia were 4.3 times more likely to live in an area dense with oil and gas wells. Drilling and fracking operations in multiple states are variously correlated with increased rates of asthma; increased hospitalizations for pneumonia and kidney, bladder, and skin problems; high blood pressure and signs of cardiovascular disease; . . . .

(*Id.,* p. 155). According to the compilers, "of the more than 1,000 chemicals that are confirmed ingredients in fracking fluid, an estimated 100 are known endocrine disruptors, acting as reproductive and developmental toxicants." (*Id.*, p. 48). Evidence of endocrine disruption in surface and groundwater samples associated with HVHF activity has been observed in different geographic regions around the country. Research has shown evidence of endocrine disrupting chemicals near HVHF projects in surface and groundwater in Colorado (Kassotis *et al.,* 2014), in surface water in West Virginia (Kassotis *et al.,* 2016) and North Dakota (Cozzarelli *et al.,* 2017), and in groundwater in Wyoming (Kassotis *et al.,* 2018). More detail on this subject is provided in Section 2.3.3.1, Drinking Water Resources, of this Comment and Response Document.

A theme of the Compendium set forth initially in the section "Introduction to Fracking," is the inadequacy of available information on the environmental and human health impacts of HVHF, a problem the editors attribute in large part to industry secrecy. They assert:

> industry secrecy continues to thwart scientific inquiry, leaving many potential problems—especially cumulative, long-term risks—unidentified, unmonitored, and largely unexplored. This problem is compounded by non-disclosure agreements, sealed court records, and legal settlements that prevent families and their doctors from discussing injuries and illnesses that result

> from fracking and frack-related operations. Consequently, no quantitative and comprehensive inventory of human hazards yet exists.

(*Id.*, p. 19).

Writing in 2019, the authors opine, "The long-entrenched problem of secrecy shows no sign of resolving." (*Id.*)(*citing* Song, 2015 and Konschnik and Dayalu, 2016).

Radionuclides/Radioactivity

One of the common constituents of the hydraulic fracturing waste stream is radioactivity, as naturally occurring substances in the targeted geologic strata are mobilized by injected fluids and brought to the surface in produced water. A regional comparison of produced water salinities indicates that in the Appalachian Basin, salinities are relatively high compared to produced water salinities in other oil- and gas-bearing formations in the United States (Rowan *et al.*, 2011).[42]

Radioactive substances, such as those commonly found in produced water and drill cuttings from shale formations, is referred to as "naturally occurring radioactive material" (NORM). When NORM has been modified by past or present human activities, such as through mobilization or concentration as a consequence of hydraulic fracturing, it is referred to as "Technically Enhanced NORM" ("TENORM"). *See* generally, Permafix, 2016. Release of TENORM into the atmosphere or environment where it can accumulate and reside for thousands of years presents a range of handling, treatment, disposal, and exposure issues. If released, deposited, discharged or spilled through HVHF activities, the concentration and persistence of these radioactive substances presents a threat of toxic exposure and/or ingestion by humans and other living organisms.

As discussed in greater detail in Section 2.3.2.2, Pollution from Spills, exposure to radium—whether internal or external—can cause cancer and other disorders. Radium emits alpha particles, which are most dangerous when inhaled or ingested. Consuming radium in drinking water can cause lymphoma, bone cancer, and leukemias. Radium and radon emit alpha and gamma rays upon their decay, which kill and mutate cells. Human exposure to radioactivity through recreational contact with water is also a valid concern. Accidental ingestion, inhalation, and in some cases dermal contact with radium isotopes in contaminated water, can have both carcinogenic and DNA-altering effects (Brugge and Buchner, 2012; ATSDR, 1990).

Bromide and Disinfection By-products in Drinking Water Sources

Disinfection byproducts ("DBPs"), created when the organic matter in surface water sources interacts with chlorine during the drinking water treatment process, are associated with increased human health risks (U.S. EPA, undated).[43] As described in Section 2.3.3.1 (Drinking Water Resources) of this

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[42] As described in Section 2.3.2.2, Pollution from Spills, radium activity is correlated with salinity, and salinity may be used as an indicator of radium activity. Thus, produced water from highly saline formations can be expected to exhibit relatively higher radium activity than lesser saline rock.

[43] We reference as "U.S. EPA, undated" EPA's web page, https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules providing background information on the need for and content of the portions of the National Primary Drinking Water Regulations codified at 40 C.F.R. Part 141 that

Comment and Response Document, bromide, a common constituent in HVHF produced water, is a particular concern in sources of drinking water, as it can contribute to the formation of toxic DBPs that arise during the treatment of drinking water. Brominated forms of DBPs are considered to be more cytotoxic, genotoxic, and carcinogenic than chlorinated species (U.S. EPA, 2016a, pp. 9-47, 8-55). Laboratory studies have shown that HVHF wastewaters diluted by fresh water collected from the Ohio and Allegheny Rivers can generate and/or alter the formation and speciation of DBPs following various treatments, even at dilutions as low as 0.01 percent (Parker *et al.,* 2014). Results of studies on disinfection byproducts are highly relevant to the Delaware River Basin, as DBP formation is already a concern in public drinking water supplies for which the Delaware River is a source (PWD, 2007). In the case of conventional wastewater treatment that may not effectively remove bromides, the discharge of HVHF wastewater to surface waters may potentially increase the formation of the more toxic species of DBPs—and thus the risk of adverse public health outcomes—in communities that withdraw drinking water from points downstream of facilities that discharge treated hydraulic fracturing wastewater.

Other Toxics Studies

As described previously, many substances used in or resulting from hydraulic fracturing activity are known carcinogens, neurotoxins, and/or endocrine disruptors, and/or are characterized by reproductive or developmental toxicity or adverse immune system effects. If these substances are not adequately removed through wastewater treatment, they may be present in downstream source water used for drinking water. A study by Yale University scientists systematically evaluated 1021 chemicals used in hydraulic fracturing fluids or found in hydraulic fracturing wastewater for reproductive and developmental toxicity. Toxicity information was lacking for 781 (76 percent) of these chemicals. Of the remaining 240 substances, evidence suggested reproductive toxicity for 103 (43 percent), developmental toxicity for 95 (40 percent), and both for 41 (17 percent). The investigators found that a federal drinking water standard or guideline had been proposed for 67 of these substances (Elliott *et al.,* 2017).

Xu *et al.* (2019) assess carcinogenicity for 1,173 hydraulic fracturing-related chemicals using the EPA's hydraulic fracturing chemical database. The investigators link the EPA data with data produced by the International Agency for Research on Cancer (IARC) at the World Health Organization and the Carcinogenic Potency Database (CPDB) from Toxnet to evaluate potential carcinogenicity for the chemicals. The authors note that they could not determine the carcinogenic potency for the majority of the 1,173 chemicals in the IARC data studied (N=989 or 84.3 percent) due to insufficient information. They conclude that of the 104 chemicals for which sufficient information existed, 14 are definitely carcinogenic, 7 are of probable carcinogenicity, and 27 are possibly carcinogenic. Using the CPDB data, the authors conclude that 66 of the chemicals are potentially carcinogenic.

Xu *et al.* further state:

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concern disinfection byproducts (DBPs). The rules themselves at Subpart L (§§ 141.130—141.135) address analytical, monitoring, and reporting requirements for DBPs and their precursors; and within Subpart F, set forth maximum contaminant level goals for DBPs (at § 141.53), maximum residual disinfectant level goals for disinfectants (at § 141.54), and maximum contaminant level goals for radionuclides (at § 141.55).

> Because the amount of each chemical and potential interaction between chemicals in proprietary fracking fluids are unknown, the exact level of cancer causing potential for exposure to carcinogen-contained fracking fluids is not clear. However, the likelihood of many if not most of the chemicals being carcinogenic in large doses or even small doses in fracking fluids is probably high.

(*Id.*). Despite the current data limitations, Xu *et al.* highlight studies which they suggest demonstrate a "potential link between risk of cancer and fracking operations." These include Finkel (2016), reporting higher than expected cases of urinary bladder cancer in both sexes in counties with hydraulic fracturing-related activities, and a study by Fryzek and others (2013) that compared incidences of cancer in Pennsylvania children before and after hydraulic fracturing ("drilling") and reported slightly higher ratios of central nervous system tumors.

Finally, Xu and his co-authors emphasize the urgency of the need for further epidemiological studies:

> Though information on the carcinogenicity of chemicals associated with HF was limited, our evaluation identified 26 known carcinogens listed in both CPBD and IARC databases. These chemicals should be given priority in the exposure assessment process for future HF-related cancer studies. Well-designed epidemiologic studies are urgently needed to investigate the potential health impacts of HF-related activities and form a scientific basis for policies.

(Xu *et al.,* 2019).

Other Public Health Studies in Pennsylvania

In December 2020, Pennsylvania Governor Tom Wolf announced the award of a $2.5 million contract to the University of Pittsburgh's Graduate School of Public Health for the purpose of studying public health effects associated with hydraulic fracturing. The contract authorizes two observational studies: 1) an investigation into the relationship between fracking and childhood cancers in southwestern Pennsylvania; and 2) an examination of acute conditions, such as asthma and birth outcomes, using regional data. The studies were undertaken in response to "concerns from families and community members impacted by cancer and other health issues in the southwestern part of the state." Completion of both studies is expected within two years. (PADOH, 2020).

Data Limitations/Gaps

As discussed in Section 2.3 regarding new rule Section 440.3—High Volume Hydraulic Fracturing, an expanding body of evidence demonstrates the toxicity of substances used and generated by hydraulic fracturing, the potential pathways of human exposure to these materials through the air, soil, and water, and, in some cases, the adverse human health effects and outcomes associated with such exposure. Of potentially greater concern, however, is what remains unknown about the human health effects of exposure to hydraulic fracturing chemicals. Section 2.3.2.2, Pollution from Spills, of this Comment and Response Document explains, among other things, that data gaps are a significant limitation on our understanding of the short- and long-term impacts of spill events. The ability to draw conclusions about the implications for human health exposure to hydraulic fracturing chemicals, fracturing fluids, flowback and produced water is similarly constrained. In its Public Health Review on the subject, the NYSDOH acknowledged:

> While a guarantee of absolute safety is not possible, an assessment of the risk to public health must be supported by adequate scientific information to determine with confidence that the overall risk is sufficiently low to justify proceeding with HVHF . . . . The current scientific information is insufficient.

(NYSDOH, 2014, pp. 11-12).

Likewise, the EPA's 2016 report highlights data limitations and uncertainty as significant factors limiting the agency's ability to fully characterize the impacts of hydraulic fracturing activities on drinking water sources (U.S. EPA, 2016a, pp. xxiv, ES-4, ES-44, ES-46, 10-24, 10-28). EPA's report identifies the factors constraining the agency's ability to characterize the public health implications of HVHF as follows:

- EPA was only able to assign standardized chemical names to 65 percent of ingredient records because the remainder did not have valid Chemical Abstracts Service Registration Numbers (CASRNs) and were thus excluded from the analysis.

- Instances in which these chemicals have been detected in drinking water resources are limited since these data are only available for a small number of chemicals.

- Our analysis focused on individual chemicals, rather than mixtures of chemicals used as additives.

(U.S. EPA, 2016a, p. 9-4)

CONCLUSION

The Commission has performed a comprehensive review of the growing body of research on environmental impacts associated with high volume hydraulic fracturing and adverse human health outcomes. Although scientific information regarding the effects of the many chemicals and agents used in and produced by unconventional oil and gas development is lacking, ample scientific information exists as to other HVHF chemicals and agents to assess whether their spill, release or discharge to the waters of the Basin would impair the effectuation of the Commission's Comprehensive Plan, including water quality objectives for surface and ground waters of the Basin. Notwithstanding the uncertainties, based on the available research, DRBC has concluded that if allowed in the Delaware River Basin, HVHF activity would substantially impair the Comprehensive Plan by impeding the effectuation of the Commission's water quality objectives for the Basin's ground and surface waters, including, among others, that "[n]o substances or properties which are in harmful or toxic concentrations . . . shall be permitted or induced by the activities of man to become ground water" (Water Code, § 3.40.5 B.1.); and that "there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values" (Water Code, § 3.10.3 A.2.).

The Commission has established by regulation with respect to ground water in particular that "Notwithstanding any other criteria or requirements of this Section, the Commission may establish . . .

prohibitions which, in its judgment, are necessary to protect ground water quality" (Water Code, § 3.40.5). The Commission has concluded that the known risks to water resources, coupled with the known health effects and uncertainty regarding the full public health impacts of exposure to HVHF substances via water and other pathways, cannot adequately be mitigated by control measures that otherwise might render such risks acceptable. The totality of the risks, vulnerabilities, impacts and uncertainties discussed throughout this comment and response document support the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.6.2 Chemical Disclosure

Statement of Concern (SC-85)

Many commenters expressed concern that the identity, formulation and toxicity of certain chemicals used in drilling and hydraulic fracturing are not known because these chemicals are classified as proprietary trade secrets and are exempt from public disclosure requirements.

The comments paraphrased below are representative of many supporting Section 440.3 of the draft rule, which would ban high volume hydraulic fracturing within the basin:

- Due to exemptions from key environmental laws and regulations, the industry is able to withhold as confidential business information the identities of potentially harmful chemicals used in hydraulic fracturing, which poses serious challenges for the protection of water resources and human health.

- The FracFocus chemical disclosure registry lists only a fraction of the chemicals used in the hydraulic fracturing process. The remainder are proprietary and not known to the public, and therefore cannot be properly regulated.

The statements paraphrased below are representative of many comments opposing Section 440.3 of the rule, which would ban high volume hydraulic fracturing within the basin:

- To maintain a high level of transparency with communities, companies report specific information about fracking fluid used at each individual well via a voluntary, publicly accessible website: FracFocus.org. To date, chemical information on over 130,000 wells is contained within the registry.

- Trade secret protection enables companies to continue to develop new and innovative products used in drilling, casing, cementing and stimulating shale gas wells and other types of wells that provide significant environmental and economic benefits.

- The combination of chemicals or "recipe" used by certain service companies that perform hydraulic fracturing operations can be of a proprietary nature and receive protections from disclosure similar to those available to other industries.

- The industry generally protects specific ingredients within additives that commonly represent less than a thousandth of one percent (0.001 percent) of the total hydraulic fracturing fluid volume. Where precise chemical identification is not publicly released, the industry typically provides categorical chemical information that allows the public to identify the class/function of the chemical. Further, several states require that the precise identity of these ingredients be disclosed to regulators, physicians, and emergency personnel.

- A framework of comprehensive chemical disclosure laws at the state and federal level, in combination with additional voluntary efforts by companies that go beyond existing legal requirements, means that an extensive amount of chemical information is readily available and is more than sufficient to demonstrate that any risks attributable to the use of chemicals in hydraulic fracturing operations are quantifiable and low.

- Pennsylvania's Act 13 of 2012 requires that service providers furnish the PADEP with a coded list of all chemicals intentionally added to hydraulic fracturing fluid by name and chemical abstract service number, even if the service provider considers that information to qualify as confidential business information. Thus, PADEP knows exactly what chemical additives are being used to stimulate a given well.

- DRBC fails to acknowledge in the background document for its proposed rules categorically banning high volume hydraulic fracturing any of the extensive sources of information regarding chemical additives used in HVHF operations.

RESPONSE (R-85)

SYNTHESIS. Chapter 5—Chemical Mixing of the EPA's 2016 report on impacts from the hydraulic fracturing water cycle on drinking water resources discusses the issue of chemical disclosure. *See* U.S. EPA, 2016a, Text Box 5-2. The oil and gas industries have been granted exemptions from specific requirements of federal statutes and/or regulations that would otherwise require the disclosure of chemicals and other ingredients used in the hydraulic fracturing process. Specifically, hydraulic fracturing is exempt from (1) the federal SDWA Underground Injection Control ("UIC") permitting requirements, (an exemption known as the "Halliburton Loophole"); (2) confidential business information ("CBI") collected by federal agencies is exempt from disclosure to requestors, and (3) oil and gas exploration and production wastes are exempt from the Resources Conservation and Recovery Act ("RCRA"), Subtitle C. An effort to require the reporting of chemicals used in hydraulic fracturing on certain federally owned or controlled lands was struck down by a federal court in 2016. *See,* Schipani, 2017 (*citing, Wyoming v. Dep't of the Interior,* No. 2:I5-CV-043-SWS (D. Wyo. Jun. 21. 2016). In the absence of federal disclosure requirements, the disclosure of chemicals and additive agents used in hydraulic fracturing may be regulated by states and other jurisdictions.

Uncertainty about the properties of the chemicals and agents mixed into frac fluid can certainly confound efforts by water resource managers to: (a) assess the risks to water resources, the environment and human health posed by spills and releases, and (b) ensure that the "produced water" returned to the surface during hydraulic fracturing and oil or gas production is properly treated, disposed of or otherwise managed.

In an attempt to address public concern regarding the composition of hydraulic fracturing fluids, the Ground Water Protection Council ("GWPC") and the Interstate Oil and Gas Compact Commission ("IOGCC") developed the FracFocus Chemical Disclosure Registry ("FracFocus"), a publicly accessible website through which oil and gas production well operators disclose information about the ingredients used in hydraulic fracturing fluids at individual wells. Although disclosure through FracFocus was initially voluntary, many states—including Pennsylvania—now require companies to disclose chemical use information through this on-line registry. According to Konschnik and Dayalu (2016), as of 2015, twenty-eight states required disclosure of hydraulic fracturing chemicals in one form or another. However, exemptions from these requirements also have been granted to allow certain information to be withheld as confidential business information or a similar designation.

In a March 2015 study on the properties of hydraulic fracturing fluids used across the nation, the EPA found that more than 70 percent of the disclosures it examined contained at least one ingredient identified as CBI, while the average number of CBI ingredients per disclosure was five (U.S. EPA, 2015a, p. 17). An effect of this exemption from disclosure is that the identity of a specific chemical may not be known for analysis, either at the time of use or at any stage that undisclosed substances are being stored, managed, or transported. Since release of the EPA's 2015 study, researchers at Harvard University found that the rate of withheld chemical identities is increasing nationally. The Harvard researchers also found that when companies follow a "systems approach"[44] to reporting chemicals (i.e., reporting without naming specific products in fracturing fluid), withholding rates decreased four-fold (Konschnik and Dayalu, 2016).

In the absence of federal requirements and given the adoption by individual states of a variety of different approaches to regulating the disclosure of chemicals used in high volume hydraulic fracturing for oil and gas development, this response will focus on the regulatory strategy currently used by Pennsylvania, the only state with territory in the Delaware River Basin in which HVHF is at present occurring. As set forth below, the PADEP expresses confidence that state regulators and other entities responsible for ensuring the safety of oil and gas development in the Commonwealth have access to information they need to safeguard the environment and public health. The Commission respects Pennsylvania's choices for the area of the Commonwealth outside the Delaware River Basin. For its part, in light of the geology of the Basin and the likelihood and severity of potential adverse water resource impacts, the Commission has determined that the risks to water resources posed by HVHF—however well regulated—are not acceptable within the Basin, a shared resource that provides the water supply for more than 13 million people in four states.

CHEMICAL DISCLOSURE IN PENNSYLVANIA

Pennsylvania Act 13 of 2012 includes two relevant chemical reporting provisions: One requires the submission of information to the FracFocus public web site[45] within 60 days after completion of

[44] According to the authors, "the 'systems approach' describes when companies report fracturing chemicals without attribution to the specific products in the fracturing fluid, to inhibit reverse engineering of any particular product used in the fracturing fluid." (Konschnik and Dayalu, 2016).

[45] The Pennsylvania statute uses the term "Chemical Disclosure Registry," which is defined as "The chemical registry Internet website developed by the Ground Water Protection Council and the Interstate Oil and Gas Compact commission or their successor organizations." (58 Pa. C.S. § 3203. Definitions).

hydraulic fracturing (58 Pa. C.S. § 3222.1(b)(2)). The second requires an oil or gas operator to submit to the PADEP within 30 days after completion of a well a "completion report" that includes a detailed "stimulation record" listing all of the chemical additives in the stimulation (fracturing) fluids. *See,* 58 Pa. C.S. §§ 3222(b) and (b.1). *See also,* 25 Pa. Code §§ 78.122(b) and (b)(6)), regulations implementing 58 Pa. C.S. § 3222(b) and (b.1).

The following remain exempt from disclosure under Act 13's provision requiring use of the FracFocus website:

- Chemicals not disclosed by the manufacturer, vendor or service provider;
- Chemicals that were not intentionally added to the stimulation fluid; and
- Chemicals that occur incidentally or are otherwise unintentionally present in trace amounts, those that may be the incidental result of a chemical reaction or chemical process, or naturally occurring constituents or materials that become part of a stimulation fluid.

See, 58 Pa. C.S. § 3222.1(c).

However, the completion report and stimulation record, which must be submitted to PADEP within 30 days of completion of an unconventional oil or gas well, must provide *all* chemical information, including any designated trade secret or confidential proprietary information. Information to be reported includes:

- A descriptive list of the chemical additives in the stimulation fluid, including any acid, biocide, breaker, brine, corrosion inhibitor, crosslinker, demulsifier, friction reducer, gel, iron control, oxygen scavenger, pH adjusting agent, proppant, scale inhibitor and surfactant.
- The trade name, vendor and a brief descriptor of the intended use or function of each chemical additive in the stimulation fluid.
- A list of the chemicals intentionally added to the stimulation fluid, by name and chemical abstract service number.

See, 58 Pa. C.S. § 3222.1 (b.1)(1)(i – iii).

In its report, the operator may designate specific portions of the stimulation record as a trade secret or confidential proprietary information, and that information is protected from public disclosure to the extent permitted by the Pennsylvania Right-To-Know Law, Act 3 of 2008.

To protect the identification of specific ingredients and formulations, PADEP has developed a coding system that allows operators to report confidential additives where the manufacturer, supplier or service company has claimed the substance is proprietary business information. However, despite public disclosure protections afforded by law, all fracturing fluid ingredients must be revealed to PADEP whether they are claimed to be confidential or not. Specifically, any manufacturer, vendor well stimulation service provider or operator claiming that a chemical is deemed to be a trade secret or confidential proprietary information ("TS/CPI") may submit to PADEP a "Registration of Trade Secret/Confidential Proprietary Stimulation Fluid Chemical Information Form." The form allows the submitter to identify the specific chemical deemed to be TS/CPI (by CAS No. and chemical name), assign a unique code to the chemical, and provide notice and justification for TS/CPI status. Upon receipt of the form by PADEP, the assigned chemical codes are entered into PADEP's database[46,47] and posted to its public website. The page of the form that associates the assigned code to the chemical's actual identity is maintained in a confidential file. Thereafter, the submitter may provide the assigned code, rather than the actual chemical identity, to the operator for inclusion in any well completion report. In the event that PADEP needs to determine the identity of a chemical identified by code in a well completion report, the confidential file may be consulted to determine the actual identity of the chemical associated with that assigned code. PADEP staff informed DRBC that as a result of this procedure, inspection staff are better aware of the actual additives being used when they are conducting on-site inspections of drilling and completion activities.

In addition to establishing the described reporting requirements, Act 13 gives the PADEP authority to require information in the course of its compliance activities that is not otherwise routinely disclosed. In particular, the PADEP has broad powers to inspect facilities and compel the production of documents concerning regulated matters, including information about regulated substances involved in any spill or release (*see* 25 Pa. Code § 78a.66). On this point, PADEP notes that 25 Pa. Code §78a.55 (i)(5)(v) requires that an Emergency Response Plan be submitted to the Pennsylvania Emergency Management Agency (PEMA), the PADEP, the county emergency management agency, and the public safety answering point (i.e., call center) with jurisdiction over the well site.

A critical assessment of unconventional oil and gas chemical disclosure requirements in Pennsylvania, the "Keystone Secrets" report prepared by the Partnership for Policy Integrity, described the limitations of Pennsylvania's chemical disclosure requirements:

> . . . Pennsylvania and 28 other states have enacted rules that require some public disclosure of these chemicals. However, most if not all of these rules have exceptions that allow companies to withhold chemical identities as trade secrets.
>
> . . . .
>
> When disclosing individual chemicals to FracFocus, well operators in Pennsylvania must include each chemical's Chemical Abstracts Service (CAS)

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[46] According to PADEP Oil and Gas Bureau Management staff, the codes are entered into PADEP's database in anticipation of future use in an online electronic completion report.

[47] PADEP has not yet developed an electronic database for its well completion reports, although it has been accepting the reports electronically since 2016. Well completion reports are publicly available and searchable by region, operator, API or US Well number, county, and municipality in the PADEP's e-Submission Tool at: http://www.ahs.dep.pa.gov/eSubmissionPublicSearch/.

> number,[48] a unique numerical identifier assigned by the American Chemical Society.

(Horwitt, 2018, pp. 4, 8)(footnote added). By consulting the FracFocus database, the public can locate unconventional gas wells in which secret chemicals have been used, but not the actual identities of the chemicals themselves. When companies involved in fracking withhold CAS numbers or other pieces of identifying information as trade secrets, well operators are required by Pennsylvania law to designate the information as a trade secret in their disclosure form filed with FracFocus. Separately, when well operators designate fracking chemicals as trade secrets in required disclosures to the DEP, they must reveal the confidential CAS numbers to the DEP, and the DEP is obligated to prevent public disclosure subject to the state's Right-to-Know Law. (*Id.*, pp. 8-9).

"Keystone Secrets" further reported that "[b]etween 2013 and 2017, drilling companies injected at least one hydraulic fracturing ('fracking') chemical with an identity kept hidden from the public into more than 2,500 unconventional natural gas wells drilled in Pennsylvania, amounting to 55 percent of the more than 4,500 unconventional gas wells drilled in the state during the five-year period, primarily in the Marcellus and Utica shale formations." (Horwitt, 2018, pp. 4, 11).

As a result, the report suggests, some chemicals—whether protected as trade secrets or not—may not be reported to either FracFocus or the PADEP. For example, Pennsylvania law does not require companies to disclose the identities of chemicals used during the well drilling phase of operations. In addition, the obligation to disclose the identities of chemicals used during hydraulic fracturing operations on a given site lies with the well operator, not with vendors, service providers or manufacturers. The Keystone Secrets report reads Pennsylvania law as absolving vendors of responsibility for inaccuracies in information provided to them by manufacturers, and as absolving service providers and operators for inaccuracies in information provided to them by vendors or other entities up the chain (Horwitt, 2018, p. 9). However, PADEP Bureau of Oil and Gas Management ("Bureau") personnel advised DRBC that in their view, 58 C.S. § 3222.1 does not explicitly absolve any parties for providing inaccurate information. Rather, the Bureau staff read the provision to hold the party that provided inaccurate information responsible for violating the reporting requirement. PADEP also notes that § 3222.1 applies only to reporting to the national registry, not to the well completion report required to be submitted to the agency under section 3222 of the statute.

Regarding the significance of limited chemical disclosure, Horwitt's report explained:

> Without knowing fracking chemical identities, citizens and regulators could have great difficulty identifying potential pollution in water supplies or determining what contaminants to remove from wastewater. Compounding the risk is that if the trade secret claims are asserted by the chemical manufacturers as opposed to other companies involved in fracturing unconventional gas

[48] According to the Keystone Secrets report, a CAS number enables scientists to determine a chemical's structure and to test for presence of a chemical in drinking water; without a CAS number, it is difficult to know what to test for. Many consider this method the best way to identify regulated substances because identical chemicals can be known by different or unique trade names, but they can only have one CAS number. (Horwitt, 2018, p. 8).

> wells, Pennsylvania law appears to provide no legal right for anyone to access the chemicals' identities, even first responders or health professionals.

(Horwitt, 2018, p. 5). In response to the latter concern, Bureau staff point out that Act 13's emergency response provisions provide for health professionals licensed by the Commonwealth to request "the specific identity and amount of any chemicals claimed to be a trade secret or confidential proprietary information" from a service company, vendor or operator if certain conditions are met. *See,* 58 Pa. C.S. § 3222.1(b)(10) and (11); *also see,* Pa. C.S. § 3219.1 and 25 Pa. Code § 78a.55 (concerning emergency response and control and disposal planning). In 2016, the Supreme Court of Pennsylvania ruled that Sections 3222.1(b)(10) and (b)(11) of Act 13 granted special treatment to the oil and gas industry without serving a legitimate legislative goal, in violation of Article III, Section 32 of the Pennsylvania Constitution prohibiting the enactment of special laws. The court declared the provisions to be void and enjoined their further application and enforcement. *See, Robinson Twp. v. Commonwealth,* 147 A.3d 536, 588-589 (Pa. 2016).

In the Bureau's view, PADEP's well completion chemical disclosure reporting regulations and compliance authorities more than compensate for the limitations of Act 13. PADEP has expressed confidence that it has the information necessary to protect public health and safety and the environment and to carry out investigations or remediations that may be necessary based on the chemicals used in hydraulic fracturing.

Conclusion

The unique risks to water resources posed by chemical use, storage and handling to support high volume hydraulic fracturing operations are discussed in detail in Section 2.3.2.2 hereof (Pollution from Spills) and Section 2.3.2.4 (Pollution from Wastewater Handling and Disposal). The Commonwealth of Pennsylvania manages these risks in part through a detailed statute and regulations focused on protecting water resources and public health while preserving commercial interests that include the interest of chemical manufacturers in protecting trade secrets. In some instances, the responses to these risks may be influenced by the timing of access to protected proprietary chemical identity information. However, the Commission has determined that no set of regulations – however extensive – can adequately control the risks, vulnerabilities, impacts, and uncertainties discussed in this Comment and Response Document, including those surrounding chemical disclosure or non-disclosure, which would accompany unconventional drilling for oil and gas in the Delaware River Basin. The totality of the risks, vulnerabilities, impacts and uncertainties discussed throughout this Comment and Response Document support the Commission's determination that prohibiting high volume hydraulic fracturing within the Delaware River Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

2.6.3 Climate Change

Statement of Concern (SC-86)

A significant number of commenters expressed concern about climate-related adverse impacts within the Delaware River Basin (DRB) and throughout the region, noting that a prohibition of HVHF would be one means of limiting the production of additional precursors to atmospheric heating. Specific noted concerns on this topic are paraphrased or quoted as follows:

Comments representative of those concerned about the climate implications of increased natural gas production follow:

- Natural gas is primarily methane, a greenhouse gas 86 times more efficient at warming the atmosphere than carbon over a 20-year time frame and its effects persist for hundreds of years.

- In 2010, the average hydraulically fractured well released an estimated 110,000 pounds of methane, a potent global warming pollutant, just in the first nine days of operation.

- The vented and fugitive losses from natural gas systems are well-documented and contribute to atmospheric warming; current technology and practices have not controlled these releases.

- The emissions from shale gas development at full build-out of Pennsylvania's Marcellus Shale play will prevent the achievement of global warming goals in the state, accelerating climate change.

- There is a delay between the build-up of greenhouse gases in the atmosphere and witnessed or perceived impacts locally, regionally and globally. Based on the current loading of atmospheric greenhouse gases, impacts are expected to intensify in the coming decades, and there is no way to know when such effects will become catastrophic.

- DRBC has not considered the effects of climate change on this area. Basin water resource managers must seriously look at how climate change will affect the watershed and how to best adapt.

- Climate change impacts on the Basin's water resources include changes in precipitation and runoff that increase flooding and drought, impairment of habitats and water quality (including saltwater intrusion to Delaware Estuary water supplies) and sea level rise.

Comments representative of those who assert that increased natural gas production helps reduce greenhouse gas emissions follow:

- The increased production and use of natural gas benefits the environment. Pennsylvania has helped lead the U.S. in the reduction of climate change emissions, thanks to increased use of natural gas in the power generation and transportation sectors.

- The U.S. leads all industrialized nations in carbon reduction because of natural gas made available through hydraulic fracturing.

RESPONSE (R-86)

The Commission appreciates the comments related to climate change generally and to the potential for impacts within the Delaware River Basin in particular. Most comments received on this issue highlighted the increasing reliance on natural gas as a regional and national energy source, and on the role of natural gas, a principal component of which is methane, in contributing to global warming. Other commenters have suggested that natural gas is a "cleaner" fossil fuel source than coal and liquid petroleum products, and that wider utilization of natural gas has contributed to a reduction in certain greenhouse gases. There are data to support both perspectives.

While greenhouse gas emissions contribute to increased warming of the Earth's atmosphere, there is insufficient data to predict the extent to which fugitive releases from future HVHF-related activities, if allowed in the Basin, would cause in temperatures, hydrologic trends, sea level rise, or other climate-related conditions within the Basin. Moreover, a prohibition on HVHF within the Delaware River Basin may create the potential for drilling activity to be more heavily concentrated in areas of the Marcellus and Utica plays in which HVHF is permitted. The outcome may simply be an altered spatial distribution rather than a net decrease in methane emissions.

Whether the growing reliance on natural gas as a fuel alternative is resulting in a net reduction in greenhouse gas emissions is difficult to gage. On the one hand, this trend has been responsible in part for a decline since 2005 in emissions of one significant greenhouse gas – carbon dioxide (CO_2). For example, the U.S. Energy Information Administration (USEIA) documented a 14 percent reduction in energy-related CO_2 emissions between 2005 and 2017 (EIA, 2018). Although CO_2 emissions from natural gas consumption grew, these increases were more than offset by reductions in coal-sourced electrical power generation. As the USEIA points out, "… because natural gas produces more energy for the same amount of emissions as coal, growth in natural gas consumption contributed to the overall 2017 decline in carbon intensity and emissions." (EIA, 2018). However, data show a reversal of the downward trend in 2018, with an increase of 2.7 percent in carbon dioxide emissions from the energy generation/use sector (EIA, 2019c; Huba, 2019). But without better data on methane emissions throughout HVHF-related activities, the net effect of HVHF on greenhouse gas emissions cannot be determined.

The DRBC is actively evaluating the impacts of climate change on the Basin's water resources and the resource management strategies that must be considered in response. Temporal, spatial and quantitative changes in precipitation, evapotranspiration and snowpack, and corollary effects on drought, flooding, and streamflow Basin-wide, as well as saltwater excursion in the Delaware River Estuary are among the observed and anticipated shifts observed as the result of a warming climate. DRBC is also examining sea level rise and its related effects. To assess impacts on the Basin's water resources and the management approaches available to address these effects, Commission staff are using regional climate projections and models based upon the representative concentration pathways for the cumulative measurement of human emissions of greenhouse gases ("GHG") from all sources, adopted by the 2013 Intergovernmental Panel on Climate Change ("IPCC").

The Commissioners and the Commission staff recognize the impacts of climate change on the water cycle and the associated water resource management challenges. In 2019 the Commission established an Advisory Committee on Climate Change ("ACCC"). The Commission along with DRBC staff and with input from the ACCC and the public, will to continue to examine policy, regulation, science, and planning direction as needed to mitigate and adapt to water resource related climate impacts. In accordance with the authority conferred on the Commission by the Delaware River Basin Compact, the final regulations on HVHF will be incorporated in and will effectuate the Comprehensive Plan for the planning, development, conservation, utilization, management and control of the water resources of the Basin to meet present and future needs.

2.6.4 Renewable Energy and Fossil Fuels

Statement of Concern (SC-87)

Other commenters emphasized the need for a transition to renewable energy sources as a basis for a "full fracking ban." Examples of their assertions are paraphrased follow:

- DRBC should not allow practices that enable more fossil fuel extraction within its jurisdiction and support a full fracking ban as being more comprehensively protective of water resources within the Basin.
- Commenters recommend pursuit of energy conservation as well as clean and renewable energy alternatives rather than continue a reliance on the development of carbon-based fossil fuels, such as fracked natural gas, which are more harmful to the environment.
- Renewable energy options are widely available, similar in cost to natural gas, and these new technologies create an abundance of job opportunities.
- Instead of an outmoded, polluting fossil fuel-based economy, we need a flourishing economy based on energy efficiency, conservation, and clean, renewable energy, an economy that will continue its record of "creating more jobs per unit of energy than coal or natural gas."
- As the global movement for divestment of fossil fuels from private and public pension funds takes hold as in cities like New York, it is becoming crystal clear that the transition away from fossil fuels is mandatory to protect the future for all. Our country needs a full ban on fracking.

Response (R-87)

Although the Commission recognizes the importance of energy conservation and renewable energy sources to any long-term national, regional or state energy policy, the Commission does not set energy policies for the nation, the region or our member states. In accordance with the authority conferred on the Commission by the Delaware River Basin Compact, the proposed rules for high volume hydraulic fracturing and related activities are limited to addressing the planning, development, conservation, utilization, management and control of the water resources of the Basin to meet present and future needs.

2.6.5 Susquehanna River Basin Policies and Reports

Statement of Concern (SC-88)

Commenters have suggested that studies by the Susquehanna River Basin Commission have shown no impacts on water resources in areas with numerous natural gas wells.

Numerous comments were received by various parties referencing natural gas activities in the Susquehanna River Basin. The commenters often refer to studies by the SRBC. Commenters included: land owners and land owner advocacy groups; oil and gas industry groups and representatives (API, Marcellus Shale Coalition, Haliburton Energy Services, PIOGA); local and regional business groups (Pennsylvania Chamber of Business and Industry, Chamber of Commerce for Greater Philadelphia, Pennsylvania Farm Bureau, Wayne Economic Development Corporation, Chamber of the Northern Poconos); and certain government and elected officials (Wayne County Planning Commission, Wayne County, PA Commissioners, Tioga County, PA Commissioners, Wyoming County, PA Commissioners, Susquehanna County, PA Commissioners; PA State Representative Jonathon Fritz; Dyberry Township, PA Supervisors).

The comments that referenced the Susquehanna River Basin studies generally stated that an SRBC report issued in 2016 found that "to date, the Commission's remote water quality monitoring network has not detected discernible impacts on the quality of the Basin's water resources as a result of natural gas development." The commenters suggested or implied that this was evidence of no impact to water resources from high volume hydraulic fracturing and therefore DRBC should not prohibit HVHF in the Delaware River Basin. In various submissions the commenters stated that DRBC ignored SRBC studies and that the SRBC has supported the conclusion that there is no negative impact and no degradation trends in ground and surface water. A smaller number of landowners commented, to the contrary, that there was evidence of private well contamination in the Susquehanna River Basin.

Response (R-88)

DRBC carefully reviewed the SRBC reports entitled "Continuous Water Quality Trends in the Susquehanna River Basin—2016 Summary Report" (SRBC, 2017) and "Continuous Water Quality Trends Adjusted for Seasonality and Streamflow in the Susquehanna River Basin" (Hintz and Markowitz, 2016), the full report on which the Summary Report is based. The SRBC statement on water quality most referenced by commenters was not presented in the "Conclusions" section of either document, but rather in the section in each on "Next Steps." The full text reads:

> To date, the Commission's remote water quality monitoring network has not detected discernible impacts on the quality of the Basin's water resources as a result of natural gas development, but continued vigilance is warranted. The Commission's next steps with the program include selecting a subset of stations with increasing conductance trends to further investigate the cause of increasing conductance.

(SRBC, 2017, p. 6; Hintz and Markowitz, 2016, p. 23)

SRBC's conclusions and underlying data indicate that there was a trend in water quality changes associated with specific conductance, which can be an indicator parameter for hydraulic fracturing aqueous wastes. The "Conclusions" section of the Summary Report states:

> The results of this study illustrated various trends in water quality parameters at a relatively small number of stations, although no clear cause or correlation with human activity could be discerned. Out of the five separate water quality parameters examined, at least one significant trend was observed at 40 out of the 53 stations. Of these 40 stations, a total of 57 significant water quality trends were identified (*see* Table 1, page 4). The Commission observed more trends for conductance than any of the other four parameters. For this reason, the stations with specific conductance trends were a major focus of the analyses. Less than 20 percent of stations with increasing conductance trends also experienced trends in dissolved oxygen, temperature, or turbidity, making it difficult to analyze for the cause of the trend.

(SRBC, 2017, p. 6). Acknowledging the need for more work to be performed, the "Next Steps" section of both reports state:

> Water quality trends will be re-examined when there are 10 years of continuous data at each station. The extended timeframe will allow for more robust analysis of the data, and also allow additional supplemental data, such as discrete water chemistry samples, to be collected in each watershed. In addition to revisiting the trends, any changes to water quality conditions will also be evaluated against the aquatic biological community data collected within the monitored watersheds.

(SRBC, 2017, p. 6; Hintz and Markowitz, 2016, p. 23). The full report states that SRBC's analysis resulted in "inconclusive evidence for the presence of fractured wells influencing conductance trends." (Hintz and Markowitz 2016, p. 14). A similar statement appears in the Summary Report (*see,* SRBC, 2017, pp. 1, 6). In most cases, commenters did not correctly interpret the conclusions of these SRBC studies.

The SRBC data do not include adequate indicator parameters related to the impacts from high volume hydraulic fracturing. SRBC's report focuses only on the water quality parameters of pH, specific conductance, water temperature, dissolved oxygen, and turbidity. Of these parameters, only specific conductance is likely to be correlated with the very limited indicator parameters for hydraulic fracturing aqueous wastes.

A 2016 report by the USGS and the Northeast Midwest Institute (USGS/NEMWI) entitled "Water data to answer urgent water policy questions: monitoring design, available data and filling data gaps for determining whether shale gas development activities contaminate surface water or groundwater in the Susquehanna River Basin," examined the SRBC's and other monitoring programs. Significant findings by the study team led by Betanzo of NEMWI included:

- The existing surface water quality data in the Susquehanna River Basin are insufficient to detect water-quality change related to shale gas development. . . .

- The publicly available groundwater quality data in the Susquehanna River Basin are not sufficient to detect whether shale gas development is contaminating groundwater, and the available data are not adequate to serve as the foundation of a new monitoring program.

(Betanzo *et al.,* 2016, pp. iv-v). A NEMWI briefing sheet accompanying the report also stated:

> Historical monitoring sites are not located near hydraulic fracturing well pads, and more recent monitoring programs lack the frequency needed to detect water quality change to support timely decision making.
>
> . . . .
>
> Recent targeted monitoring programs through the Susquehanna River Basin Commission and Pennsylvania Department of Environmental Protection are monitoring in appropriate locations, but additional sampling frequency, parameters, and streamflow data are needed before water quality trends can begin to be detected.

(NEMWI, 2016, p. 1).

DRBC has not ignored the SRBC data. As noted, the data do not comprehensively or definitively address the question of long-term impacts to water resources. If a study were to be undertaken to address long term water resource impacts in the Susquehanna River Basin by either the PADEP, PADCNR, SRBC or others, the USGS/NEMWI (Betanzo *et al*. 2016) study should be used as guidance for scope development. Section 2.3.3.1, Drinking Water Resources, of this Comment and Response Document discusses cases of impacts to water resources in the Susquehanna River Basin from high volume hydraulic fracturing activities, including impacts to private drinking water wells.

A 2019 "Technical Summary" by the SRBC describes results from the SRBC's Remote Water Quality Monitoring Network ("RWQMN") for 16 selected stations (from among the full network of 59 stations) in watersheds that drain portions of, or that flow through, state forest lands (Berry, 2019). Although the purpose of the technical summary is not stated, the report documents statistics on three continuous monitoring parameters, a water quality index based on nine other parameters, and an analysis of biological monitoring. The technical summary report itself contains no conclusions. However, following its release, it was cited by others as evidence that HVHF activity has no adverse effect on water resources (*see, e.g.,* Shepstone, 2019). DRBC has found that the results presented in the report are inconclusive regarding impacts of HVHF activity in the Susquehanna River Basin for the reasons set forth below:

- The report describes some possible explanations for selected results but does not rule out impacts from natural gas development or state any conclusions regarding impacts of the natural gas industry on surface water quality. The report does not conclude that natural gas development has had no impact on monitored streams.

- The drainage areas for the 16 stations monitored are not representative of the range of intensity of HVHF activity in the Susquehanna River Basin. None of the 16 stations monitors a stream draining an area characterized by a well pad density of greater than 0.6 pads/mi^2. Seven of the other RMQMN stations (not included in this report) monitor streams draining areas with well pad densities greater than 0.6 pads/mi^2 and as high as 1.27 pads/mi^2.[49] None of the 16 stations is located downstream from a HVHF wastewater treatment plant.[50] Impacts to surface waters in the Susquehanna River Basin caused by treatment plants treating HVHF wastewater have been documented elsewhere (*see, e.g.*, U.S. EPA, 2018b). The 16 drainage areas covered by the SRBC's 2019 report account for only 4 percent of the Susquehanna River Basin.

- The report uses a Water Quality Index ("WQI") that does not relate closely to potential HVHF impacts. The WQI is designed to relate to other human activities: abandoned mine drainage, agriculture, and urban development (Berry *et al.,* 2020). As a result, the relation of the WQI to potential HVHF impacts is unclear. The nine water quality parameters used to calculate the WQI do not include many that are most indicative of HVHF activity, such as barium, bromide, calcium, gross alpha, gross beta, lithium, magnesium, radium-226, radium-228, strontium, suspended sediment, total dissolved solids, uranium, and specific conductance. The water quality of a stream might be rated "good" or "excellent" according to the WQI, yet the stream could be impacted by one or more of these other HVHF-related constituents.

- Although the report lists the fractured well density in each monitored drainage area, no attempt is made to relate this factor or other natural gas metrics to any water quality results.

- The scope of the report does not include any analysis of water quality trends. Trends in water quality parameters could provide an early indication of water quality degradation, even in waters that meet water quality criteria and are considered to have "good" water quality.

- As described previously, the study by the Northeast-Midwest Institute and the U.S. Geological Survey concluded that the existing surface water quality data in the Susquehanna River Basin are insufficient to detect water-quality change related to shale gas development (Betanzo, *et al.,* 2016). If impacts to water quality from HVHF activities are occurring, they may not be detected through analysis of the data being collected in the Susquehanna River Basin.

The PADCNR Bureau of Forestry partnered with SRBC and others to conduct additional water-quality monitoring of streams in Pennsylvania state forest lands where HVHF activities have occurred. More

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[49] *See,* https://mdw.srbc.net/remotewaterquality/ the web page from which information on SRBC's Remote Water Quality Monitoring Network can be retrieved. The page includes links to "watershed profiles" that include watershed area and number of natural gas drilling pads, among other types of information) for each monitored stream.

[50] Id.

than 97 percent of all Pennsylvania state forest land within the core gas forest districts are within the Susquehanna River Basin. A report on these monitoring efforts concluded in part:

> Water quality monitoring efforts by the bureau and its partners have not raised significant concerns on state forest headwater streams to date. However, these are still relatively short-term results and may not be indicative of long-term or cumulative effects that can only be detected through long-term monitoring efforts.

(PADCNR, 2018).

Again, DRBC has not ignored Susquehanna River Basin data; we have carefully reviewed the data, and we are fully aware of the reliable scientific analysis that demonstrates the limitations of the available data for the Susquehanna River Basin.

Statement of Concern (SC-89)

Commenters observed that the DRBC and the SRBC have several of the same members, yet they have different policies on natural gas development.

Response (R-89)

The DRBC and the SRBC are both interstate-federal river basin management agencies. Each was created by its basin states and the federal government through concurrent legislation in the form of an interstate compact approved by Congress under Article 1, Section 10, Clause 3 of the United States Constitution. The Commonwealth of Pennsylvania and the State of New York are signatories of both compacts. In addition to these two states, the SRBC also includes Maryland (for a total of three states), while the DRBC includes New Jersey and Delaware (for a total of four states). The federal member of the two Commissions is the same – the Division Commander of the U.S. Army Corps of Engineers. However, state representation on the two Commissions differs. In accordance with the respective compacts, DRBC's state members are the duly elected Governors of the signatory states. In contrast, SRBC's state members are "the governor or the designee of the governor of each signatory state." Historically, the Governors of New York, Maryland and Pennsylvania have appointed the chief executive of their environmental agencies as SRBC Commissioners. The Commissioners of both SRBC and DRBC generally appoint one or more alternates to act on their behalf; however, the Commissioners for the DRBC member states are elected officials (the Governors of the respective states) and the Commissioners for the SRBC member states have historically been appointees of the Governors.

A substantive difference between the two compacts, rooted in the very different history and geography of the two basins, is in the language of their respective Articles 5. Article 5 of the Delaware River Basin Compact, titled "Pollution Control," opens with the statement, "The Commission may assume jurisdiction to control future pollution and abate existing pollution in the waters of the Basin, whenever it determines after investigation and public hearing upon due notice that the effectuation of the [Commission's] comprehensive plan so requires." Article 5 of the SRB Compact, titled "Water Quality Management and Control," includes language that, although similar, appears six paragraphs into Article 5, and only after a provision expressly stating that "[t]he legislative intent in enacting this article is to give specific emphasis to the primary role of the states in water quality management and control." The statement in Article 5 of the SRB Compact excludes the phrase "to control future pollution and abate existing pollution."

Pollution control was one of the principal reasons the DRBC was created, and as such, has been a central focus of the Commission's work since its inception. DRBC has established uniform water quality standards in the Basin, particularly within the main stem Delaware River. It has taken a leading role in restoration of the Delaware River Estuary, which is impaired by legacy pollution from industrial activity that occurred prior to the enactment of the Delaware River Basin Compact and key federal and state environmental laws. In this regard:

- DRBC established and together with the signatory parties has implemented waste-load allocations that have restored dissolved oxygen in the Estuary from concentrations incapable of supporting aquatic life to the vastly improved levels we have today, which support robust fish populations. More information on this program can be found on the DRBC website here.

- DRBC spearheaded a program that has made tremendous progress in reducing contamination from polychlorinated biphenyls (PCBs), which continue to be the cause of state-issued consumption advisories for multiple species of Estuary fish. More information on this program can be found on the DRBC website here.

DRBC also has taken the lead in protecting interstate waters of exceptionally high quality, including the main stem Delaware River from Hancock, New York, to Trenton, New Jersey. Through DRBC, the Basin states and federal government established the Special Protection Waters program to protect the exceptionally high water quality of the non-tidal Delaware River. The goal of this antidegradation program is no measurable change in existing water quality except toward natural conditions. More information on this program can be found on the DRBC website here. In contrast with DRBC's long history, policies and accomplishments in water quality restoration and protection, due to its different Compact language, geological setting, use of water resources, pollution challenges and other factors, SRBC has focused its regulatory authority almost exclusively on issues related to water quantity.

STATEMENT OF CONCERN (SC-90)

Commenters suggested that the proposed prohibition in the Delaware River Basin relies upon the designation of the drainage area as Special Protection Waters yet drilling in the Susquehanna River Basin include similarly classified High Quality and Exceptional Value waters.

RESPONSE (R-90)

Acting jointly through the DRBC after significant public input, the member states and federal government have classified all the non-tidal portions of the Delaware River as "Special Protection Waters" (SPW) due to their exceptionally high scenic, recreational, ecological, and/or water supply values. It is expected that practically all the development and related disturbances from high volume hydraulic fracturing would occur in the drainage area to approximately 144 river miles (73 percent) of the Basin's SPW waters. Notably, a 73-mile reach of the main stem Delaware River overlying the Marcellus and Utica Shales also is among multiple stream reaches within the Delaware Basin that have been included by the United States Government in the National Wild and Scenic Rivers system. Such a designation has not occurred in the neighboring Susquehanna River Basin on the main stem Susquehanna River.

In the Susquehanna Basin, all surface water quality classifications are established by the member states for waters within the state; none are classified jointly as in the case of DRBC's SPW. Pennsylvania's surface water quality classifications include the designations "Exceptional Value" (EV) and "High Quality" (HQ) for high quality waters, and these classifications have been applied to thousands of miles of streams in both the Susquehanna and Delaware basins. Table 10 compares river (or stream) miles assigned Pennsylvania anti-degradation classifications within the portions of the two basins underlain by the Marcellus and Utica Shales.

	River Basin	
	Susquehanna	**Delaware**
Total River Miles in areas underlain by Shale Formations	24,782	4,391
Total High Quality (HQ) and Exceptional Value (EV) River Miles in same areas	8,167	3,627
% HQ and EV River Miles	**33%**	**83%**

Table 10: Special protection (EV and HQ) river miles

If the Delaware River SPW designation is included in the tabulation, the percentage of river miles with anti-degradation classifications within the portion of the Delaware River Basin underlain by the Marcellus and Utica Shales rises to 86 percent.

In addition, under the 1954 Supreme Court Decree in *New Jersey v. New York,* 347 U.S. 995 (1954) a diversion of up to 900 million gallons per day of water may be exported from the Delaware River Basin to support the water supply needs of millions in New York City and portions of New Jersey outside the Basin. It is possible that because out-of-basin diversions from the Susquehanna are not nearly as significant as from the Delaware, a comparable level of concern on the part of out-of-basin water users regarding the sufficiency and quality of main stem flows has not arisen in connection with SRBC's hydraulic fracturing permitting actions.

Statement of Concern (SC-91)

A commenter suggested that SRBC studies indicate no discernible impacts on groundwater in the Susquehanna River Basin.

Response (R-91)

The SRBC studies do not include an evaluation of groundwater resources in the Susquehanna River Basin. That conclusion cannot be reached without additional information.

As noted in a prior response, USGS/NEMWI (Betanzo *et al.,* 2016) found that current water quality monitoring is inadequate for detecting potential surface water or groundwater impacts of shale gas development activities in the Susquehanna River Basin and that the publicly available groundwater quality data in the Susquehanna River Basin are not sufficient to identify water quality change related to shale gas development and are not adequate to serve as the foundation of a new monitoring program. The study also presents recommendations to implement a systematic, long-term groundwater monitoring program for detecting groundwater quality change related to shale gas development in the Susquehanna River Basin (Betanzo *et al.,* 2016).

Statement of Concern (SC-92)

Commenters stated that regulatory programs such as those used by SRBC can be adopted by DRBC to protect the water resources in the Delaware River Basin.

Response (R-92)

SRBC's water accounting and water withdrawal rules and standards provide for the management of routine water acquisition and consumptive water use for hydraulic fracturing. As discussed in the response above in this section, a substantive difference between the two compacts, rooted in the very different history and geography of the two basins, is in the language of their respective Articles 5. Article 5 of the Delaware River Basin Compact, titled "Pollution Control," opens with the statement, "The Commission may assume jurisdiction to control future pollution and abate existing pollution in the waters of the Basin, whenever it determines after investigation and public hearing upon due notice that the effectuation of the [Commission's] comprehensive plan so requires." Article 5 of the SRB Compact, titled "Water Quality Management and Control," includes language that, although similar, appears six paragraphs into Article 5, and only after a provision expressly stating that "[t]he legislative intent in enacting this article is to give specific emphasis to the primary role of the states in water quality management and control." The statement in Article 5 of the SRB Compact excludes the phrase "to control future pollution and abate existing pollution." As such, SRBC rules do not address water quality and pollution control risks associated with hydraulic fracturing and would not adequately protect DRBC water resources and Special Protection Waters.

Statement of Concern (SC-93)

Commenters stated that, as specifically noted in the US EPA report regarding the Susquehanna River Basin, evidence suggests that current water management strategies protect streams from depletion, and multiple studies have shown that hydraulic fracturing has had minimal impact on drinking water resources in the Susquehanna River Basin. In addition to the water supply availability authority of both SRBC and DRBC, any water withdrawals associated with unconventional natural gas development also is subject to oversight by PADEP through the submittal, review and approval of water management plans.

Response (R-93)

There are several references to Susquehanna River Basin water resources in the 2016 EPA Study. The Executive Summary, when discussing water acquisition suggests that *"studies in the…*

Susquehanna River basin found minimal impacts on drinking water resources from hydraulic fracturing." (U.S. EPA, 2016a, p. ES-13). The more detailed discussion of water acquisition management is provided in Chapter 4 of U.S. EPA, 2016a. DRBC acknowledges that SRBC has provided management practices to minimize any localized impacts during the water withdrawal and water acquisition process and those management examples are provided in U.S. EPA, 2016a. Like the SRBC, water management plans submitted to PADEP for hydraulic fracturing-related water acquisition within the DRB would require review by the DRBC. The frequency and severity of vulnerabilities related to water acquisition are identified in Chapter 10. In general, these vulnerabilities are not as significant as others discussed in the report.

Significantly, U.S. EPA did not fully consider the impact of a multi-year drought in the Susquehanna River Basin. The 2015 EPA report on impacts of water acquisition in the Susquehanna River Basin for hydraulic fracturing states only that "Shortages may develop during droughts, and low flow periods in the smaller streams, but intrinsic vulnerability to water shortages is generally relatively low." (U.S. EPA, 2015b, p. 96).

The drought of record for the Delaware River Basin occurred in the 1960's, when the Basin experienced eight consecutive years of below normal precipitation. Most of the water used for hydraulic fracturing is consumptively used and not returned to the resource. While it may be feasible to interrupt the consumptive use of water for a period of time during short duration "droughts" or intermittent periods of low flow, the impacts may be more severe when extended droughts occur. EPA, 2016a did not address how consumptive uses from high volume hydraulic fracturing projects could be replaced by consumptive water users to ensure a safe and reliable water supply for public health and safety during a repeat of the worst drought of record (at a minimum). In addition, U.S. EPA, 2016a does not address the question of who will allocate available water to meet the highest priority public health and safety needs when water is most scarce.

2.6.6 Economic Impacts

Statement of Concern (SC-94)

The Commission requested and received numerous comments highlighting the statewide (Pennsylvania) and regional economic benefits and harms that would accompany either high volume hydraulic fracturing (HVHF) or a prohibition on HVHF within the Delaware River Basin.

Comments describing the economic benefits the authors believe to be associated with HVHF were included in 5,900 form letters from individuals, ten letters or multi-part submissions from business and industry groups (the Chamber of Commerce for Greater Philadelphia; Petroleum Equipment & Services Association; American Petroleum Institute; Halliburton Energy Services; Marcellus Shale Coalition, PA Independent Oil & Gas Association, Pennsylvania Farm Bureau, Chamber of the Northern Poconos, Wayne Economic Development Corporation, and Pennsylvania Chamber of Business and Industry); and seven letters from government officials (Wayne County Planning Commission; Wayne County, PA Commissioners; Tioga County, PA Commissioners; Wyoming County, PA Commissioners; Susquehanna County, PA Commissioners; PA State Representative Jonathon Fritz; and Dyberry Township, PA Supervisors).

Comments claiming that the benefits attributed by some to HVHF are overstated or that HVHF causes economic harms were included in numerous letters from individuals and eleven letters or multi-part submissions from organizations (including: Natural Resources Defense Council; PennFuture; Damascus Citizens for Sustainability; Delaware Riverkeeper Network; NJ Sierra Club; New York Sustainable Business Council; New Jersey Sustainable Business Council; American Sustainable Business Council; Trout Unlimited; Wayne County Camp Alliance; and Friends of the Upper Delaware).

Comments representative of those predicting economic benefits from natural gas development in the basin follow:

- The DRBC rule proposal fails to incorporate any information for consideration by the public on what could be lost economically as the result of an extended prohibition on oil and natural gas development in the Basin or, conversely, what could be gained economically from a less aggressive approach.

- According to its mission, the DRBC must consider and integrate environmental and economic needs in determining whether to amend its regulations to prohibit HVHF in shale and other geologic formations.

- "Natural gas extraction can be part of a balanced fuel development economy and bring some wealth to Pennsylvania; however, fracking requires thoughtful and thorough regulation AND tax revenue so that the people who do not own large tracts of fracked lands are compensated for the risks and burdens this industry brings with it."

- "It is possible to have a clean, sustainable Delaware River and economic growth and development, and the original purpose of the DRBC was to promote economic development. This [natural gas] resource is our economic development in northeastern Pennsylvania – don't take it away."

- The natural gas industry provides affordable energy for millions of Americans and contributes to the nation's energy self-sufficiency, which is critical to the environment, job creation, the economy, and national security.

- "The natural gas industry has boosted economic development and has had a positive impact on many industries, including agriculture. The positive impacts have been widespread, and the financial benefits to Wayne County have allowed us to accomplish great things for our citizens."

- It is indisputable that the oil and gas industry has made a substantial contribution to Pennsylvania's economy overall.

- "Responsible development of oil and natural gas from unconventional formations, such as shale, presents an unprecedented opportunity to provide sustainable and broad-based economic benefits to Pennsylvania and the nation."

- The economic and social impacts of natural gas development within the Delaware River Basin will be significant and positive – contributing to the prosperity and economy of our region.

- Abundant natural gas is fueling the development of an ethylene cracker plant by Shell Oil Company in Beaver County, PA, which will provide for a significant economic infusion and numerous construction jobs and permanent jobs.

- Local infrastructure is in the best condition seen in recent memory due to upgrades and repairs made or funded by natural gas development companies.

- Revenue from leases on private land to support natural gas development offers supplemental income to farmers and is an essential component of their economic well-being.

- A prohibition on hydraulic fracturing in Pennsylvania's northeastern counties, which are among the Commonwealth's poorest due to a lack of a diversified economic base, deprives its citizens of a necessary economic stimulus.

Comments representative of those foreseeing economic harm from natural gas development in the basin follow:

- The economic benefits of inexpensive natural gas would not outweigh the risk of pollution to the Delaware River Basin.

- The water resources of the Delaware River Basin contribute significantly to the annual economic activity and support a significant number of direct and indirect jobs in the coastal, farm, ecotourism, water/wastewater, ports and recreation industries. Clean water is a foundation for all of these industries.

- "The Delaware River was designated as a national Wild and Scenic River by the U.S. Congress because of its outstanding natural features, irreplaceable resources, exceptional water quality and scenic and recreational value.

  - "These prized assets provide important economic benefit to all four states whose tributaries flow to the Delaware River.

  - "The value of these assets is gravely jeopardized by hydraulic fracturing and its polluting operations and must be protected for the public and future generations."

- The Delaware River and its tributaries provide multiple benefits to the surrounding area. As a natural environment, the waters provide vital habitat for trout and the aquatic ecosystem in general. As such, the Basin's high-quality water resources provide economic benefits to the businesses and towns that serve this region.

- The economy in our community is largely tourism-based (fishing, biking, camping), and if hydraulic fracturing were allowed, that base would be destroyed.

- Summer camps for children are one of our area's most valuable industries. The Delaware River Basin is the home of some of America's oldest and most successful summer camps. Millions of dollars in revenue are brought into our area because of camps, including visitors, jobs, and industry. The continued success of camps hinges on maintaining the pristine, environmentally sound character of Northeastern Pennsylvania. Hydraulic fracturing activities would destroy the natural beauty and peace that so many families seek in choosing a camp.

- Historically, people bought real estate primarily because this area remained unspoiled; however, new clients refuse to buy unless they can be assured the property is not near a drilling operation. The area attracted retirees, secondary home buyers, river users, artists, writers, and professionals who came for the natural beauty and were willing to commute to metro areas, all because this was a better life and a better environment for their children and grandchildren.

- A minority of property owners of large tracts of land would benefit from shale gas extraction, while the vast majority of residents would suffer the negative impacts.

- I have visited Susquehanna County. The natural gas industry has brought a few good-paying jobs to that area, but almost entirely for workers from Oklahoma and Texas.

- Fracking operations also bring new, transient populations into small towns, requiring new infrastructure and housing and increasing the number of alcohol-related crimes, traffic accidents and rates of sexually transmitted diseases (Hauteur, 2016). The workers eventually move on, leaving behind unnecessary infrastructure and a "ghost town" feel.

Numerous comments, along with the studies and reports referenced in those comments, indicate that natural gas development using high volume hydraulic fracturing (HVHF) promises economic gains through oil and gas revenues, employment growth, lease and royalty payments to some landowners, indirect benefits to local businesses, reduced natural gas costs for consumers, and local/regional host benefit disbursements through Pennsylvania Act 13. Other commenters asserted that if HVHF were to be allowed in the Basin, any economic gains would be offset by adverse economic impacts associated with HVHF. These commenters averred that the economy of the Basin areas underlain by gas-bearing shale depends on clean water, open space and the unique natural character of the region, which, they contend, would be irreparably altered, compromised or destroyed by the impacts of hydraulic fracturing, including air and water contamination; diminished stream flows; fragmented forests, wildlife habitat and farmland; increased noise, traffic congestion and crime, and impairment to traditional businesses and occupations.

Response (R-94)

In responding to comments about the potential economic benefits and harms of HVHF, the Commission has relied, where appropriate, on credible available research beyond that referenced by commenters. The most comprehensive economic analysis submitted by a commenter was that by ALL Consulting, LLC ("ALL"), on behalf of the American Petroleum Institute ("API"). Accordingly, ALL's economic assumptions and conclusions are discussed in detail in the Commission's response to comments.

Natural Gas Development Potential in the Delaware River Basin

ALL's economic analysis begins with an estimate of the natural gas development and production potential in the Delaware River Basin ("DRB"). ALL defines an "anticipated production extent" ("APE") that is coterminous with the boundaries of the Utica and Marcellus Shale "plays"[51] within the Pennsylvania portion of the Basin, as these plays are defined by geology reviews published by the U.S. Energy Information Administration ("EIA").[52] For the Marcellus, a limited portion of Wayne County alone falls within ALL's projected APE, while for the Utica, portions of six Pennsylvania counties are included in the APE.

ALL next calculates the anticipated development associated with high volume hydraulic fracturing in the Delaware River Basin as follows:

> To estimate the future oil and gas exploration and development activities that might reasonably be expected to occur in the DRB over the next 10 years, an analysis of the PA drilling permits issued, and wells drilled between 2013 and 2017 within counties in proximity to the DRB was conducted. The forecast was based on the area's geology and historical and present activity, as well as factors such as economics, technological advances, access to oil and gas areas, transportation, and processing facilities.

(ALL Consulting, 2018, p. vi). ALL acknowledges that identifying gas reserve boundaries and high productivity areas entails approximation, noting that the extent of these features is:

> controlled by key geologic criteria that include thermal maturity, total organic carbon (TOC) content, formation thickness, porosity, depth, pressure, and the ability of the formations to be hydraulically fractured. Chief among these geologic criteria is thermal maturity as crude oil and natural gas are produced by heating the organic materials (i.e., kerogen) found in organic-rich rocks, usually shales.[53]

ALL further acknowledges that "The PADEP [oil and gas] map . . . seems to indicate a decline in operator activity from west to east in Susquehanna County, as well as a decline from north to south in Wyoming County." Ultimately, ALL characterizes the development potential of both the Marcellus and Utica formations in each of the six counties within the Delaware River Basin as "LOW," stating, "The low rankings for development potential reflect the thermal maturity of shales in the eastern

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[51] In mineral resource development parlance, a "play" is an area in which hydrocarbon accumulations or prospects of a given type occur (Schlumberger, undated).

[52] Based on updated 2017 mapping and data from the U.S. Energy Information Administration, the eastern edges of the Marcellus and Utica shale plays extend into the upper northwest portion of the DRB within Pennsylvania (EIA, 2017a; and EIA, 2017b).

[53] In explaining how thermal maturity in shales is estimated from core samples, ALL Consulting notes that "oil and gas zone boundaries are often established using vitrinite reflectance data; however, the boundaries are approximate and can vary according to kerogen type."

portion of the state and the lack of past activity . . . ." (ALL Consulting, 2018, p. 14).[54] ALL's analysis leads it to assume that an estimated 40 HVHF wells will be developed per year over a ten-year period in six northeastern Pennsylvania counties within the Delaware River Basin. In ALL's assessment, fifteen (15) wells per year are projected to be developed in the Wayne County portion of the Basin, and the remaining development (25 wells per year) is expected to be spread across all or portions of five other counties—Carbon, Lackawanna, Luzerne, Monroe, and Pike.

In the Commission's view, ALL's projections of potential economic benefits to be generated from HVHF do not account for relevant geological information and field observations that suggest the potential for commercial natural gas development in the Basin may actually be limited. Without specific justification, ALL assumed that the entire Basin area underlain by the Marcellus and Utica plays holds commercially viable quantities of natural gas. As described in Section 1.7, the geologic setting of the Delaware River Basin differs in many respects from other areas underlain by the Marcellus and Utica formations. The available geological information, field data and experience suggest that the potential for natural gas development in the Basin may be limited. For example:

- ALL's report considers the 60-square-mile portion of Wayne County, Pennsylvania within the Susquehanna River Basin to be productive; yet, no natural gas development has occurred there.

- Similarly, in the portions of Lackawanna and Luzerne counties in the Susquehanna River Basin that overlie the Marcellus Shale play within the Susquehanna River Basin, no unconventional gas development or production has taken place.

- PADEP maps and records display a fairly defined arc of plugged natural gas wells five and more miles west of the Delaware River Basin divide. Immediately west of this arc, drilling activity appears to be extremely dense, while immediately east of it, active gas wells are entirely absent.[55] ALL's report does not acknowledge or explain the presence of the plugged wells, the density of natural gas drilling activity immediately to their west, or the absence of such activity to their east.

- Retired Penn State University geosciences professor Terry Engelder has referred to a Marcellus "line of death" (Engelder's term), representing the estimated margin at which the Marcellus Shale play reaches thermal over-maturity, or the transition point at which commercially viable quantities of dry natural gas have been effectively "baked out" over geologic time (Zhou *et al.,* 2017). Figure 17 illustrates the location of the so-called "line of death" relative to the Delaware River Basin's western boundary.

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[54] Referencing the Pennsylvania DEP Interactive oil and gas map at https://www.depgis.state.pa.us/PaOilAndGasMapping/OilGasWellsStrayGasMap.html).

[55] The arc of plugged unconventional wells roughly coincides with the Lackawanna Synclinorium, a banana-shaped geologic feature that once contained much of Pennsylvania's anthracite coal reserves. This roughly 70-mile long formation curves northeastward generally along the SRB/DRB divide, extending from central Columbia County into Wayne County.

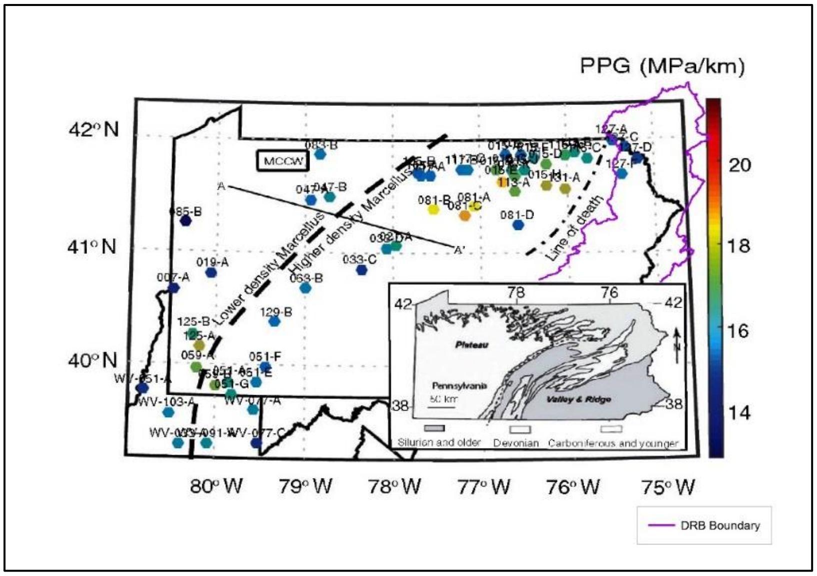

Figure 17: Marcellus Shale "Line of Death"
Source of base map (excluding Basin boundary and caption): Zhou *et al.*, 2017.

In their study of sonic properties in the Marcellus Shale, Zhou and co-authors Engelder and Nikoosokhan explain the significance of the "line of death" this way:

> The line of death is vernacular for the boundary between the region of economic gas production from the Marcellus and the region where test wells may have shown gas but not in economic volumes.

(Zhou *et al.,* 2017).

- The belief that the Marcellus Shale may be over-mature toward its northeastern margin is shared by geologists who reason that the extreme pressures and temperatures responsible for creating the once-plentiful, geologically younger[56] anthracite coal reserves in northeastern Pennsylvania may have "cooked out" any natural gas present in the Marcellus Shale in this zone, converting the gas to carbon dioxide (Skrapits, 2012). If the hydrocarbon content in the Marcellus is over-mature in a given area, then the older, deeper, hotter and more pressurized Utica Shale beneath it likely has been depleted of natural gas as well.[57]

- Active gas wells in Pennsylvania are located in close proximity to (and at least one within several hundred feet) of Pennsylvania's boundary with New York State, where high volume

[56] The shales and coal in this region were formed during various periods of the Paleozoic Era—the Utica during the Ordovician period (approximately 440-485 million years ago); the Marcellus during the Devonian period (about 360-420 million years ago), and the northeastern Pennsylvania anthracite coal beds during the Carboniferous period (roughly 300-350 million years ago).

[57] Skrapits (2012) reports that Professor Engelder has acknowledged that these observations are generalized, and that in-depth geochemical analysis is required to confirm how far the over-maturity extends and what promise, if any, the shales in this region hold in terms of natural gas production.

hydraulic fracturing was prohibited in 2015 after an exhaustive environmental and public health impact analysis. The proximity of producing wells to the Pennsylvania – New York border indicates that the state boundary is the controlling natural gas development factor along the boundary with New York State. In contrast, the absence of producing and active natural gas wells in Pennsylvania within approximately five miles of the Delaware – Susquehanna River Basin divide suggests that other factors, such as geologic characteristics and field exploration results, have contributed to the lack of development along the Basin divide (*see* Figure 18).

The ALL report analyzed average per-well gas production in Susquehanna County and used these data as a proxy for the expected average per-well production for counties in the Delaware River Basin, an approach that in view of the foregoing geological observations appears flawed. There is little indication that the level of production in Susquehanna County is likely to continue to the east. To the contrary, as Pennsylvania's Office of Oil and Gas Management program mapping tool[58] illustrates, drillers have to date left untouched a miles-wide swath of land along the county's entire eastern border, widening in the northeast and southeast corners of this rectangle-shaped jurisdiction. If the area were rich in extractable gas, it is reasonable to expect that operations would have expanded into this area. Based upon the density of existing gas development, the production history and the criteria (thermal maturity, total organic carbon content, formation thickness, porosity, depth, pressure, and the practicability of the formations to be hydraulically fractured) used by ALL to characterize anticipated natural gas production in the six Delaware River

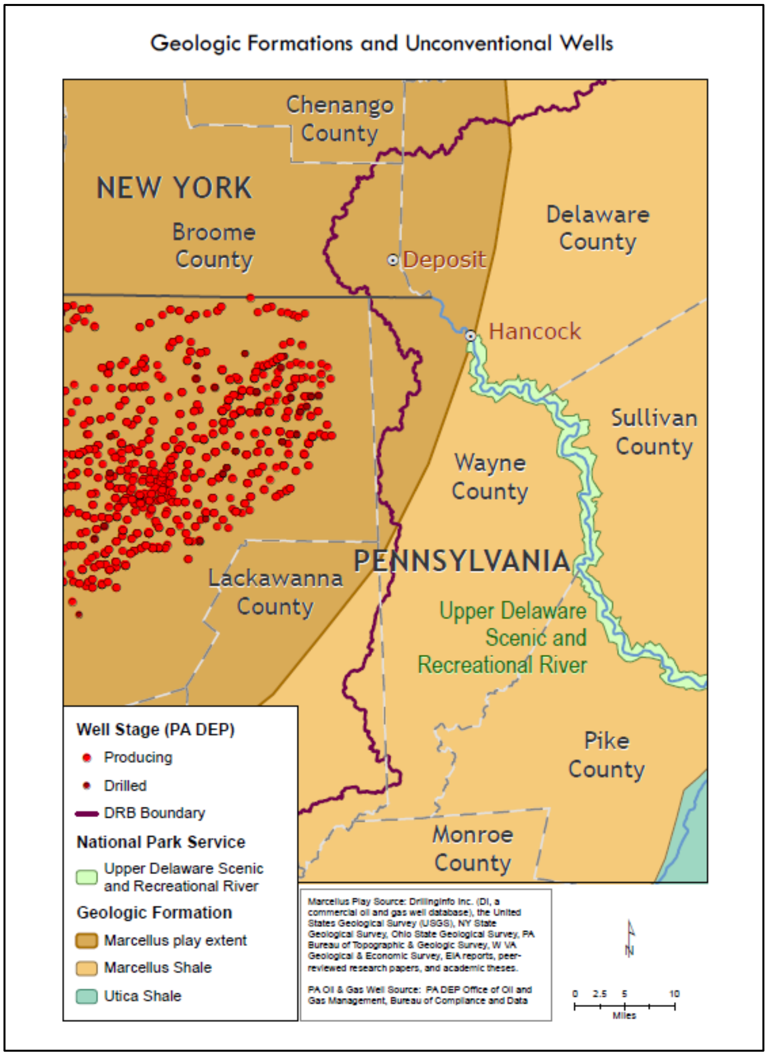

Figure 18: Distribution of Unconventional Natural Gas Wells in Northeastern Pennsylvania

[58] *See* PA DEP's interactive GIS database at: https://www.depgis.state.pa.us/PaOilAndGasMapping/OilGasWellsStrayGasMap.html.

Basin counties as "LOW," the apparently "HIGH" natural gas development potential of Susquehanna County would seem to make it an unreliable predictor of potential in the Delaware River Basin.[59]

Like Susquehanna County, Lackawanna County lies directly west of the counties straddling the Delaware—Susquehanna Basin divide. Yet Lackawanna County, which adjoins the easternmost section of Susquehanna County to the south, is as devoid of natural gas development as the eastern margin of Susquehanna County. ALL fails to explain why the experience in Lackawanna County is not a valid predictor of production in any of the Delaware River Basin counties. A more impartial authority, the USGS, has observed in reference to the shales underlying the DRB that, "[a]t shallower depths and where the formations have been disturbed by tectonic forces, it is less likely that a commercial natural gas reservoir is present or can be developed." (USGS, 2018, p.13).

For the reasons set forth above, whether sufficient quantities of dry natural gas exist to support commercial production in the Delaware River Basin remains in question in the Commission's view. At the least, there is strong evidence to suggest the potential for natural gas production from shales within the Delaware River Basin is lower than ALL predicts. Because ALL's assumption that 40 wells per year will be developed in the six Pennsylvania counties within the Basin over an initial period of ten years is dubious, its ten-year natural gas production estimate of 14.3 billion cubic feet (Bcf) for the Basin is equally suspect, as are ALL's estimates of the economic value of gas production in the Basin.

The analysis of potential natural gas development within the Basin performed by Habicht and Faeth (2015) for CNA Associates (CNA) on behalf of the Delaware Riverkeeper Network is also of doubtful use in predicting the economic value or opportunity cost of a prohibition on HVHF in the Delaware River Basin, but for different reasons. Assuming an absence of restrictions on natural gas well construction in any region of the Basin, including New York State, CNA projected the development of ten times more wells in the DRB over a ten-year period than ALL for API. CNA avers that its analysis is "useful for identifying which portions of the Marcellus Shale may be most suitable for development (relative to all the others) …" and professes that its estimate of the impacts from hydraulic fracturing "should be viewed as a first iteration of investigating a range of potential impacts." (Habicht *et al.,* 2015). CNA's analysis does not address the unique geologic factors present in northeastern Pennsylvania; nor does it acknowledge or attempt to explain the lack of hydraulic fracturing activity to date immediately west of the Delaware River Basin.

In sum, both ALL and CNA assume that significant quantities of commercially recoverable natural gas exist throughout the Delaware River Basin in spite of evidence that suggests otherwise, or that at the very least highlights a lack of information sufficient to support reliable expectations or estimates.

Estimated Economic Value of Hydraulic Fracturing

The ALL report relies on a non-peer-reviewed 2011 study by Considine and others funded by the Marcellus Shale Coalition (MSC) for the claim "that each Marcellus Shale well in Pennsylvania generates $6.2 million in economic impact in the state." (ALL Consulting, 2018, p. 36, citing Considine *et al*.

[59] At least one major oil and gas development company has charted its future in Susquehanna County, explaining: "As a result of our strategic transformation in 2017, Cabot enters 2018 as a pure-play Marcellus Shale company focused on our low-cost, high-return position in Susquehanna County, Pennsylvania." (Cabot, 2018).

(2011), which relied on two earlier reports: Considine *et al.,* 2010 and Considine *et al.,* 2009). The $6.2 million-per-well estimate is based upon 2008 well drilling data. The ALL investigators used a well head gas price of $2, $3, and $4 per Mcf, for a single well with assumed production decline over time (the average wellhead price for natural gas in 2019 averaged near the low end of ALL's estimates at roughly $2.33 per million cubic feet). Although prevailing market conditions will define gas prices at any given point in time, the assumed range of natural gas prices used by ALL appears reasonable. Regardless, the use of a reasonable well head price range does not validate ALL's results.

In 2017, the Center for Rural Pennsylvania (CRP) conducted a study for the purpose of "us[ing] the growing number of economic studies . . . to examine the economic implications of Marcellus Shale activity in Pennsylvania" (*see,* Hesse *et al.,* 2017). The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania's rural and small communities. The CRP study examined economic factors impacting natural gas development in southwest and northern Pennsylvania. Notably, the CRP acknowledges the study performed by Considine *et al.* for the MSC but qualifies its references to that study by emphasizing that the MSC-funded work was not peer-reviewed. The authors state further:

> As the shale gas industry is still relatively new in Pennsylvania, early analyses relied on data collected in the industry's infancy. Many were not peer-reviewed, which means the studies were not independently and anonymously reviewed by other researchers to ensure the methods and analysis were accurate. Such 'blind' peer review is an important standard for scientific studies. In addition, many early studies lacked longitudinal data and required significant assumptions about the pace and location of development. . . .
>
> Now that the shale gas industry has been active in the commonwealth for nearly a decade, sufficient longitudinal data have become available to better estimate the economic changes associated with Marcellus Shale development. The peer-reviewed literature on economic impacts significantly expanded in 2015, and several additional studies are forthcoming. Addressing limitations of early studies, these newer analyses now incorporate data and models that can better reflect the varied paces and intensities of development over the last decade.

(Hesse *et al.,* 2017 (internal citations omitted)).

The CRP's statements cast considerable doubt on the 2009-10 studies by Considine, and by extension, on Considine's 2011 study and ALL's analysis. ALL Consulting's questionable assumptions go beyond its reliance on early, non-peer-reviewed predictions cited in an industry-funded report. ALL assumed that if, as a result of DRBC regulation, 40 wells are *not* drilled in the Delaware River Basin, then those wells will not be drilled in Pennsylvania at all, and the economic value to the Commonwealth will be entirely lost. However, unconventional natural gas production is driven chiefly by geologic, technological and market conditions. The emergence of new high-productivity development areas, enhanced or expanded production at existing sites, and increased production through longer lateral extensions indicate that existing and potential areas of production in Pennsylvania outside the

Delaware River Basin are far from being saturated. The Delaware River Basin is not the only remaining area of hydrocarbon mineral development opportunity, and extraction technologies may also evolve. From both a geological and market perspective, areas outside the Basin are likely to remain preferable in terms of oil and gas development for some time. Accordingly, DRBC's proposed action may result in little or no lost revenue to the Commonwealth for many years, if at all.

Again, in reliance on Considine's 2011 study funded by MSC, ALL assumes that 780 to 1560 new jobs are created annually for every 40 new wells drilled per year. A more recent, peer-reviewed economic study by Hoy and co-authors published in 2017 discredits the input-output model and assumptions used by Considine (Hoy *et al.,* 2017).

Hoy *et al*. focused on assumptions about how industry spending is represented and how leasing and royalty dollars are spent. Relying on detailed county records and a survey to develop actual data and compare it to the findings forecast by Considine *et al.* (2009, 2010), Hoy *et al*. (2017) concluded that the economic value added was much less and the jobs added considerably fewer than Considine and his co-authors predicted. Specifically, the Hoy study found that actual employment and value added were roughly *half* that reported by Considine *et al.* The primary drivers for the lower results were transient labor and a more accurate accounting of where lease and royalty payments were spent/invested (e.g. out of state, in state lands, or in savings which may or may not reside in Pennsylvania) (Hoy *et al.,* 2017).

In sum, the ALL Consulting report uses dated assumptions from a dated, industry-funded, non-peer-reviewed study that overstates economic benefits. As the 2017 CRP study reports, more recent and reliable data tell a different story:

> In June 2015, CWIA [Pennsylvania Department of Labor Center for Work Information and Analysis] released a new calculative approach that found that more than 33,000 people were directly employed in oil and gas (CWIA 2015b), and around 56,000 indirect and induced jobs were associated with Marcellus [s]hale [d]evelopment. Therefore, more than 89,000 jobs, in total, were attributable to shale gas development (CWIA, 2015a; 2015b). These new estimates are starkly different from early industry funded studies, but more consistent with academic economic research conducted over the last 6 years.
>
> . . . .
>
> These [later] studies suggest that any impacts to employment . . . from shale gas development are modest. Key issues that need to be closely considered when interpreting employment numbers include how much of employment activity involves local workers, how much involves non-local workers coming temporarily into the community, and how employment may change through the life cycle of shale gas development.

(Hesse *et al.,* 2017, pp. 15-16).

If viable "anticipated productive extent" areas exist within the Delaware River Basin, and if such areas are developed for natural gas, then the economic benefits would be substantially smaller than ALL suggests. Moreover, contrary to ALL's claims of a significant statewide impact from added jobs and economic value, the economic benefits of developing the Basin for natural gas would accrue to relatively few Pennsylvanians.

Specifically, the CRP found that "employment and compensation [associated with hydraulic fracturing for the extraction of natural gas from shales] are generally found to be less significant than income generated from leases and royalties." (Hesse *et al.,* 2017, p. 32). The CRP's findings:

> . . . indicate that the . . . economic benefits are not necessarily community-wide, but rather accrue to a smaller subset of the population (or even non-residents), and are determined by factors such as mineral rights ownership, age, gender, and employment status.

(Hesse *et al.,* 2017, p. 1).

As early as 2012, peer-reviewed research reported that the experienced and specialized workforce demanded by the mineral extraction industries typically is transitional, meaning that the more technical and lucrative positions are often filled by skilled individuals who move from one play to another as the market dictates. As a result, locales that lack a suitably skilled workforce may not fare as well economically as those in which an experienced labor set is more established (Weber, 2011). This concern was voiced by several commenters who averred that the majority of better-paying unconventional oil and gas jobs go to migratory industry workers. Ancillary concerns are that the influx of a mobile workforce to perform these better-paying jobs creates an acute short-term demand for lodging, goods and public services, but when the higher-paid mobile workers move on to the next drilling region, a legacy of under-utilized infrastructure is left in their wake.

Weber's findings, based on an analysis of the effects of a natural gas boom on employment and income in Colorado, Texas and Wyoming, suggest these commenters' concerns are warranted. His research indicated that:

> a natural gas boom should increase total employment and income because of higher wages caused by a combination of greater demand for labor, an increase in the number of jobs (which may be filled by local or outside workers) and rent payments to private and public resource owners. Growth in aggregate employment and income, however, does not imply that median income will increase or that the poverty rate will decrease. The distribution of the gains will depend heavily on the skills of local residents and where they fall in the distribution of income, the extent that local and regional labor markets are integrated, and the size of spillovers into non-booming sectors.

(*Id.*).

The CRP reports that drilling "a well produces more jobs than later stages of development, meaning employment and compensation impacts will likely occur early in development." (Hesse *et al.,* 2017). However, even this observation must be qualified, as the increasing specialization and technological advances that created the hydraulic fracturing boom may also reduce the need for local labor. For example, a recent development introduced by Schlumberger involving automation of some aspects of the hydraulic fracturing process reportedly could reduce community employment opportunities even farther (Jacobs, 2017). In a May 2017 story in the Journal of Petroleum Technology, Jacobs (2017) listed among the benefits of an "automated stimulation delivery system," the prospect that "oil and gas producers will need fewer people and less time to drill and complete their wells."

NATURAL GAS ROYALTIES

ALL estimates that 40 wells drilled per year could generate between $143 million and $286 million dollars over ten years based upon a 12.5 percent royalty[60] on production revenue. ALL even suggests that a 20 percent royalty – the high range of royalty payment values – should be assumed. ALL does not mention that most lease royalties are subject to deductions for post-production costs. Although many mineral rights owners in Pennsylvania have benefited from royalty payments, the assumption that new gas leases could include and actually yield a 20 percent royalty is misleading, because deductions for post-production costs often result in payments that are less than the Pennsylvania statutory minimum of 12.5 percent. Pennsylvania's experience with lower-than-expected royalty payments has resulted in both individual and class action lawsuits alleging underpayment of royalties by producers. In 2015, Pennsylvania's Attorney General brought such a suit on behalf of the Commonwealth, lodging the complaints, among others, against industry defendants that:

> . . . money was wrongfully deducted from royalty checks as a result of wrongful . . . conduct.
>
> . . . Landowners entered into lease agreements . . . for royalty payments in reliance upon representations that their royalty payments would not be reduced by deductions for post-production costs.
>
> . . . Landowners entered into lease agreements through a bait and-switch scheme . . . .
>
> [Defendant] engaged in a self-dealing scheme which resulted in increased deductions . . . .

Commonwealth v. Chesapeake Energy Corp. et al., 206 A.3d 51 (Pa. Cmwlth. 2019), allocatur granted Oct. 30, 2019, appeal dockets 81 MAP 2019 and 82 MAP 2019 (Case No. 2015IR0069), Compl. ¶¶ 1–4. An interlocutory appeal in the Attorney General's lawsuit remained pending as of June 2019 and the matter had not yet gone to trial. Meanwhile, a bill introduced during multiple sessions of the Pennsylvania House of Representatives (HB 1684, Reg. Sess. 2013-2014; Reg. Sess. 2015-16; HB 1391, Reg. Sess. 2016-17; and HB 557, Reg. Sess. 2017-18, respectively), but which was not enacted, would guarantee a royalty of at least 12.5 percent to Pennsylvania lessors *after* any deduction of post-production costs. The repeated failure of this legislation to become law is an indication that ALL's

[60] Under Pennsylvania's Oil and Natural Gas Lease Act, 58 Pa. Stat. §§ 901-905, any leases concluded on or after September 18, 1979 must provide at least a one-eighth (12.5%) royalty rate to be valid. As with other major oil and natural gas producing states, the owners of the natural gas (e.g. the operator and the leaseholder) proportionally share the expenses required to get the natural gas to market for sale, unless the parties have mutually agreed to a different arrangement.

royalty assumptions may be flawed and that actual royalty payments will continue to fall below 12.5 percent in many cases.

Based on ALL's assumption that an estimated 40 wells per year would be developed within the Basin absent DRBC's prohibition, ALL further assumes that between 40 and 80 well *pads* per decade would be developed (each with an estimated five wells) (ALL Consulting, 2018, pp. vii-viii). Assuming these projections were accurate, how many Pennsylvania residents would benefit directly from lease payments and royalties? The Commission submits that if each pad involved 1-2 lessors, an estimated 40-160 Pennsylvania landowners, among the approximately 5.4 million Pennsylvanians who reside in the Basin and rely on its water resources, could potentially derive direct economic benefit from natural gas lease payments and royalties over a ten-year period.

Natural Gas and Oil Impact Fees (Pennsylvania Act 13)

The Commission posits that, if high volume hydraulic fracturing (HVHF) were not prohibited in the Basin, the market – not access to marginally productive shales underlying parts of the Delaware River Basin – would drive the number of new HVHF wells in the Marcellus and Utica regions of Pennsylvania. Accordingly, the Commission believes ALL overstates the opportunity cost of a Basin-wide prohibition on HVHF in statewide benefits from impact fees,[61] drilling permit fees and income taxes. As noted above, the area of productive extent for natural gas extraction within Pennsylvania is far from saturated, and in the Commission's view, restrictions on HVHF in this Basin will have little if any effect on drilling and production statewide or associated state revenues over the next decade.

A prohibition on HVHF within the Delaware River Basin could affect the distribution of Pennsylvania Act 13 "impact fee" revenues to local governments. In principle, these fees are intended to offset the costs the industry inadvertently imposes on host communities and the state in administrative and infrastructure expenses, including road and bridge repair, traffic control, emergency services, and social services attributable to the industry's activities. If HVHF is prohibited in the Delaware River Basin, the adverse impacts that Act 13 fee revenues are intended to address will not occur here, and the expenses required to mitigate these impacts will be unnecessary.

ALL's Conclusions

ALL concludes that "over the 10-year development period … state and private revenues generated by the development of natural gas would be significant, with estimates ranging from $148 million to $475 million annually." (ALL Consulting, 2018, p. vi.). Although ALL did not provide a summary table, the Commission has constructed one by adding ALL's estimated contributions from each of the revenue sources presented in its report. As Table 11 indicates, ALL appears to have miscalculated the total "high end" of the annual economic value range and to have overstated this sum by $120 million

[61] Act 13 of 2012 amending Title 58 (Oil and Gas) of the Pennsylvania Consolidated Statutes was signed into law by Governor Tom Corbett on Feb. 14, 2012. Act 13 provides for the imposition of an unconventional gas well fee (also called an impact fee) and mandates how the fee proceeds are disbursed to local and state entities and the purposes for which these proceeds may be spent. A significant portion of the funds collected are distributed directly to local governments to cover the local impacts of drilling. Several state agencies also receive funding to be used for a variety of other purposes (PA PUC, 2012).

per year. In addition, ALL's estimate of economic benefits is flawed in the Commission's view, as a result of the following incorrect assumptions made by ALL:

- a significant volume of commercially viable gas is available in the Delaware River Basin through high volume hydraulic fracturing;
- gas production in Susquehanna County accurately represents anticipated production in the Delaware River Basin; and
- wells not drilled in the Delaware River Basin over the next 10 years will not be drilled elsewhere in the Commonwealth.

	ALL Report Estimates	
Annual Economic Value from All Report (millions)	Low Range	High Range
Value of Production	$ 114.6	$ 229.1
Lease Bonus Payments	$ 6.4	$ 64.3
Royalties	$ 14.3	$ 45.8
Unconventional gas impact fees	$ 12.6	$ 12.6
Drilling permit fees	$ 0.2	$ 0.2
Individual income taxes on royalty payments	$ 0.4	$ 1.4
State income taxes on bonus payments	$ 0.2	$ 2.0
Calculated Total	**$ 148.7**	**$ 355.4**
Total Stated in ALL Report	**$ 148.0**	**$ 475.0**
Overstated Difference	**$ (0.7)**	**$ 119.6**

Table 11: ALL Report Summary of Economic Value Estimates

As a result of these inaccurate assumptions, the Commission believes that both the low-end and the high-end economic benefit projections developed by ALL are significantly inflated. Peer-reviewed studies not funded solely by industry generally support the Commission's view. For instance, in a summary of research findings on the economic impacts of mineral extractive industries, one report noted:

> Any economic activity, including shale gas development, will generate some level of state and local economic revenues and provide some number of state and local employment opportunities, but policymakers should recognize that the estimated gains in revenues and employment are probably exaggerated in the industry-funded studies and the long-term economic impact may be far different than expected.

(Barth, 2013).

In addition, the proposed rules do not prohibit the extraction of oil and natural gas within the Basin using methods other than high volume hydraulic fracturing; however, ALL did not provide an estimate of the natural gas reserves and economic benefits to be derived through forms of extraction other than high volume hydraulic fracturing, which benefits could offset the identified opportunity costs associated with a prohibition of HVHF within the Basin.[62]

OTHER ECONOMIC CONSIDERATIONS

Over the past decade, research on the economic impacts of natural gas development has largely focused on the factors discussed above – employment, royalties, impact fees, taxes and indirect benefits. However, factors and forces on the macroeconomic scale also may play a role in local and regional economies. Additional research describes a "natural resource curse," characterized by boom-and-bust cycles, and several studies have examined broader and longer-term economic trends. Key points conveyed by this work include:

- Direct economic gains tied to resource extraction are experienced primarily by oil and gas corporate interests and a fraction of local residents. In many cases, host communities experience a "boom-bust" economy (Putz *et al.,* 2011, pp. 6-7, 15-16; Jacquet, 2009). Muehlenbachs *et al*. (2015) wrote:

  > Economic and environmental impacts may also arise from the "boomtown" phenomenon, where local areas facing shale development see increases in population, employment, business activity, and government revenues. However, boomtowns may also suffer from negative social, economic, and environmental consequences such as increased crime rates, housing rental costs, and air pollution. Furthermore, the "boom" may be followed by a "bust" if benefits from shale gas development are only temporary. Local public goods might be expanded during the boom at considerable cost only to be later left underutilized, and sectors with better growth potential could contract during the boom, leaving the area worse off in the long run. . . .
  >
  > (Internal citations omitted).

- A frequent theme in the economic research is the "natural resource curse" (Sachs and Warner, 2001) in reference to the phenomenon of abundant natural resources coupled with a decline in overall economic growth in a region (Barth, 2013 (referencing Stevens, 2003)). Although seemingly counter-intuitive, research shows that dependence on non-renewable natural resources such as oil, natural gas or minerals, as a single or primary revenue source, can lead to impaired long-term economic growth. A general explanation of this outcome is that a concentrated emphasis and investment in one specialized industry comes at the expense of other economic investment, especially where a strong, diversified economy may not be in place prior to the emergence of the new booming industry.

[62] In its proposal and its final rule to amend the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities (18 C.F.R. Parts 401 and 440), and with specific reference to certain forms of hydraulic fracturing it sought to prohibit, the DRBC defines "high-volume hydraulic fracturing" as "hydraulic fracturing using a combined total of 300,000 or more gallons of water during all stages in a well completion, whether the well is vertical or directional, including horizontal, and whether the water is fresh or recycled and regardless of the chemicals or other additives mixed with the water."

Studies and data have indicated that natural gas development results in some positive economic benefit, especially in jobs and wages directly associated with aspects of hydraulic fracturing operations and resource processing. The overall economic impact from high volume hydraulic fracturing, as reported in the most reliable research on the topic, however, is mixed.

Adverse Economic Impacts and Harms

To fairly describe the economic benefits from high volume hydraulic fracturing (HVHF), the adverse impacts that accompany this industry must also be considered. Research shows that the costs are borne disproportionally by local and regional communities around which HVHF-related facilities are sited. These costs may not be immediately apparent. They may also persist long after the final unconventional natural gas well ceases production. Many commenters suggested that HVHF would permanently harm the unique character of the Basin and result in adverse impacts to existing economic drivers in the region such as agriculture, recreation and eco-tourism, diminishing the quality of life that residents of the Basin currently enjoy.

A common critique of studies funded and/or referenced by oil and gas interests is that they seldom accurately account for the negative consequences of these industries, such as the costs of pollution containment and abatement, restoration of degraded natural resources, and other adverse community and environmental impacts. Two factors hamper an accurate quantification of such costs:

1) the hydraulic fracturing process at its present scale is relatively young (especially in Pennsylvania) and some of the potential problems may not yet be apparent; and

2) the difficulty of reliably assigning monetary values to externalities such as increased noise, traffic congestion, lost scenic vistas or altered rural character.

Several recent studies sought to gauge what might be characterized as indirect effects or implications attributable to hydraulic fracturing. Gopalakrishnan and Klaiber (2014) conducted an empirical study that sought "to measure the impact of early shale exploration [in Washington County, Pennsylvania] as capitalized into surrounding property values." The authors chose Washington County because the "high density of residents in close proximity to recent Marcellus Shale exploration activity … [make] it an ideal location to study the impacts of shale exploration on surrounding property values." (Gopalakrishnan and Klaiber, 2014). Their study found that adverse property valuations associated with shale gas development depended on a home's proximity to and the intensity of shale activity. The study also found that shale activity disproportionately impacted households that rely on well water and are located relatively close to major highways or in more rural areas. The negative impacts were observed to diminish over time, coinciding with the cessation of exploration activity.

The findings specifically reported that households that relied on well water and were located within three-quarters of a mile of an active well site experienced a 21.7 percent decrease in home values.

In their study, Gopalakrishnan and Klaiber found relevant some of the more common irritations that many commenters cited as concerns related to high volume hydraulic fracturing – traffic, noise and visibility of well pads. Increased traffic and congestion during and following production can be significant problems and are commonly reported as such. Citing the New York State Department of Environmental Conservation's Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program on this issue, the researchers reported that:

> . . . prior to and during exploration activity, truck traffic in the area is likely to be greatly increased. It is estimated that a horizontal well experiences an average of 230 one-way heavy truck trips and an additional 230 one-way light truck trips prior to actual drilling (spud date), and an average of 1,145 one-way heavy truck trips and 830 one-way light truck trips by the completion of activity.

(Gopalakrishnan and Klaiber, 2014).

A survey of Pennsylvania residents in October 2009 found that more than 63 percent of respondents in areas with high drilling activity reported significantly increased traffic and congestion associated with trucks compared to just 12 percent of respondents in less impacted areas (Schafft *et al.,* 2012).

Two additional hydraulic fracturing-related impacts were suggested as probable factors that could adversely affect nearby homeowners and influence prospective homebuyers. Elevated noise levels during well pad construction, horizontal drilling and well production, compared to "ambient rural noise levels," would be readily apparent within at least a half-mile from an active well pad (Gopalakrishnan and Klaiber, 2014). Additionally, with heights up to 150 feet, drilling rigs are likely to be seen from great distances, even in hilly wooded landscapes. In citing work by Upadhay and Bu, Gopalakrishnan and Klaiber 2014 note that the addition of horizontal lighting at night accentuates the presence of well pads in dark rural skies, an additional possible adverse effect on neighbors.

Gopalakrishnan and Klaiber's findings are similar to those of Muehlenbachs *et al*. (2015), who reported a property value impact of *minus* 24 percent for households near well pads and that also relied on wells as their primary drinking water source. In summarizing their results, the latter further noted:

> While it is clear that the perceived risk of groundwater contamination negatively impacts property values, homes that rely on piped water may in fact benefit from being adjacent to drilled and producing wells … driven by royalty payments (or expectations of royalties) from productive wells. However, it is evident … that the positive impacts from being in close proximity to a [natural gas] well diminish as that distance becomes very small. The overall positive impacts are net impacts of being near a [gas] well; i.e., net of any negative environmental externality (such as light and noise pollution from drilling) that is common to all properties regardless of drinking water source. Thus, even homes with piped water are better off being slightly farther from a well, as long as they are able (i.e., not too far) to capitalize on lease payments.

(Muelenbachs *et al.,* 2015). Greenstone *et al*. (2019) summarize the external costs associated with hydraulic fracturing, including deterioration in the non-economic quality of life or total amenities, as follows:

> There were also costs. Combining the effects on housing prices and earnings with an economic model, the authors estimate that fracking reduces the typical household's quality of life by about $1,000 to $1,600 annually. These factors included an increase in truck traffic, more noise and air pollution from

> drilling activity, beliefs regarding negative health effects, and higher rates of crime despite a 20 percent increase in public safety expenditures. … This data indicates that the average local benefits from hydraulic fracturing outweigh the costs, though this may change as more information about the environmental and health impacts of hydraulic fracturing is revealed.

Some of the adverse impacts that may arise from HVHF may be at least partially mitigated by industry-funded impact fees and tax revenues, such as Pennsylvania's Act 13 unconventional gas well fees. However, the costs associated with many of these impacts – noise and air pollution, crime, depressed property values, surface and ground water contamination (including contamination of drinking water sources), roadway deterioration and traffic congestion, land clearing/disturbance, forest fragmentation, altered natural character, and impacts to other natural resources, including wildlife and habitat – are difficult, if not impossible, to valuate monetarily and cannot be mitigated or replaced readily if diminished, lost or destroyed.

A number of the individual commenters provided estimates of the economic value of the Delaware River Basin's natural water-based resources, many without specific references or cited sources. Such estimates and claims will not be discussed here. Two basin-wide economic studies by Kauffman were cited most frequently and are discussed in further detail below. Additional specialized and local economic studies cited by commenters are also discussed below.

In a peer-reviewed report which updated his 2011 study, Kauffman (2016) estimated the socioeconomic value of the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania. This study concluded that the Basin's water resources:

- Provide ecosystem goods and services (natural capital) of $21 billion per year (in 2010 dollars), and

- Are directly/indirectly responsible for 600,000 jobs with $10 billion in annual wages.

Kauffman and Homsey (2013) provided a more focused study with the objectives of (a) estimating the economic value of potentially recoverable shale gas in the Delaware River Basin with protective buffers in place and (b) comparing that to the value of renewable water resources such as drinking water, forests, and river-based recreation. This study concluded that the combined annual value of drinking water, forests, and recreation, which depend on renewable natural resources (i.e., water) in the Delaware River Basin, exceeds the value of potentially recoverable Marcellus Shale gas, a nonrenewable resource. Other specific findings include:

- In the Delaware Basin, the annual economic value of natural resources ranges from $425 million for potentially recoverable Marcellus Shale gas to $942 million for river recreation, $2.8 billion for drinking water, and $4.2 billion for forest ecosystems.

- The Delaware Basin downstream from the shale region provides up to 1.6 BGD of treated drinking water with an annual market value of $2.8 billion to cities such as New York City, Philadelphia, Allentown, Easton, Trenton, and Wilmington.[63]
- Over 2/3 of Marcellus Shale watersheds in the Delaware Basin are covered by vast forests that provide annual ecosystem services worth $4.2 billion—$3.1 billion in New York and $1.1 billion in Pennsylvania. Up to 10 percent of the forests may ultimately be disturbed by shale gas drilling with a $366 million loss in ecosystem services.
- In the Pennsylvania and New York portions of the Basin, agriculture contributes approximately 26,500 jobs and $1.2 billion in wages.
- In the Marcellus Shale region in the Delaware Basin, the annual value of river-based recreation for tourism, boating, fishing, hunting, wildlife viewing, swimming, and skiing is $942 million.

See, Kauffman and Homsey, 2013.

Both the Kauffman and Homsey (2013) and Kauffman (2016) reports include annual economic value estimates for large areas of the Basin that might or might not experience economic losses associated with high volume hydraulic fracturing if permitted. Kauffman and Homsey (2013) concluded that the annual combined value of natural system services in the Basin exceeds the annual value of potentially recoverable natural gas. We also recognize, however, that if permitted, HVHF would not result in the complete loss of the value of natural or water resource systems within the Basin.

That HVHF activities could result in economic harm either locally and/or downstream of HVHF development areas is acknowledged. However, an equal or greater threat of adverse economic impacts throughout the region is posed by the appurtenant activities, such as material hauling, natural gas processing and distribution, and waste management, which, like well pads, would be dispersed across the landscape. Even so, these activities would not be expected to result in a complete loss of water resource-related assets or attendant values. No commenter submitted an analysis focused on the potential diminution of economic value of natural resource services as a result of HVHF activities within the Basin.

Several commenters suggested that HVHF could result in adverse economic impacts and harm to the local recreational economy, specifically the fishing industry. In addition, it is worthy to note that the DRBC received 101 form letters from "anglers" supporting a full ban on hydraulic fracturing in the area. Two studies that attempted to place an economic value on the fisheries industry are:

[63] As we explain in Section 2.3.2.1 (Water Use) of this Response to Comments Document, the Delaware River Basin water supply objectives and flow management operations can be significantly impacted by any consumptive use, including high volume hydraulic fracturing, during periods of low flow and drought. Added to daily diversions of up to 900 MG to support New York City and New Jersey water supply demands, withdrawals for consumptive use can impact downstream water availability and the management of salinity in the Delaware Estuary, where public water supply intakes for the City of Philadelphia and for a large New Jersey purveyor, among others are located.

- A 2014 Economic Impact Study for the Upper Delaware River by Shepstone Management Company concluding that the cold-water fisheries industry contributes approximately $21 to $26 million in economic value to the region (Shepstone, 2014).

- A 2017 study by the National Park Service concluded that visitors to the Upper Delaware National Scenic Recreation Area resulted in an economic value of about $11 million annually to the region (Thomas, 2018).

These studies were referenced by commenters who implied or stated there was potential lost value due to hydraulic fracturing activities. Neither of these two studies were specifically performed to address the economic impacts of hydraulic fracturing. As with the Kauffman studies discussed above, estimates of economic value cannot be assumed to be estimates of complete loss of economic value due to the hydraulic fracturing activities.

Studies by Kellison *et al*. (2017), Barth (2013), and Rumbach (2011) examined the potential impacts of hydraulic fracturing on local tourism. Barth and Rumbach described the potential cumulative impacts of hydraulic fracturing in the following ways:

> Increased truck traffic, automobile traffic, air pollution, noise pollution, and industrial accidents, decreased availability of hotel/motel rooms, campground spaces, and RV parking, negative visual impacts from multiple drilling rigs in rural viewsheds, storage facilities, gravel pits, and compressor stations, disruptions to wildlife and hunting grounds, fears over lake and stream pollution . . . will change the character of the region from pristine and rural to gritty and industrial. If so, the region's ability to attract tourism may be damaged in the long term. . . .

(Rumbach, 2011).

> Public fears of water, air, and land contamination due to shale gas development, whether those fears are realistic or not, may forever negatively impact the public perception of the rural areas that currently enjoy tourism dollars.

(Barth, 2013).

Kellison and co-authors examined and surveyed users of public parks near hydraulic fracturing operations and concluded that more than half of all respondents expressed: concern that a fracking operation would limit their ability to access their park (52 percent); were willing to travel farther to visit a park unaffected by fracking (56 percent); and supported legislation prohibiting fracking near their favorite park (58 percent) (Kellison *et al*. (2017)). While many studies have raised issues about potential economic harms, few have attempted to quantify the value lost, and most recognize the uncertainty of any estimates of potential economic benefits or harms.

With regard to agriculture, many farmers with substantial property, especially if they own the attached mineral rights, may benefit from bonuses, lease payments, and royalties connected to gas and oil extraction. For small and mid-sized farm operators in particular, such payments may supplement income, alleviate debt, protect marginal farm livelihoods for future generations, or allow the operators to diversify or transition out of agriculture altogether. Despite the windfall experienced by some, however, according to one study, many Pennsylvania farmers have faced procedural inequities in negotiating and enforcing oil and gas lease terms, and after doing so, experience growing dependence on unstable revenue from leases coupled with increased environmental risk. (Malin and DeMaster, 2015). Describing these patterns as a form of rural environmental injustice, Malin and Demaster relate Based on 42 in-depth interviews, the Malin and DeMaster report that:

> The farmers in our study who owned small and midsized operations felt constrained to accommodate particular industry practices that often included increased exposure to myriad environmental risks and uncertainties. For operators of these farms, environmental risks—now increasingly documented across the US—include: public health impacts, such as increased rates of birth defects within a half mile of wellpads; water contamination, including loss of household water quality; harm to livestock; increased traffic, noise and light pollution; decreased property values; inequitable and restricted access to information about chemicals used in unconventional production; disturbed landscapes; and diminished quality of life.

(*Id.*) (internal citations omitted). "When seeing the impacts to their farms," the authors relate, "some regretted their decision to sign leases. Far from the glamorous worlds of the 'shaleionaires,' these farmers struggle to receive royalty payments, face a busting natural gas economy, and contend with abundant environmental risks and uncertainties." (*Id.*) (internal citations omitted).

CONCLUSION

DRBC's Notice of Proposed Rulemaking specifically requested input on economic considerations. The Commission reviewed and considered the comments received and related economic studies in conjunction with their decision to adopt the final regulations. The Commission concluded that the potential economic benefits of HVHF were overstated by the commenters who supported allowing HVHF in the Basin, and concluded such benefits do not outweigh the adverse economic effects, injuries to water resources and impairments to the uses of water resources protected by the Comprehensive Plan that would result if HVHF were permitted in the Basin.

2.6.7 Recreational Uses

Protected uses in the Comprehensive Plan include: agricultural; industrial; public water supplies after reasonable treatment (except where natural salinity precludes such uses); wildlife, fish and other aquatic life; recreation; navigation; waste assimilation (to the extent that such use is compatible with other uses); and such other uses as may be provided by the Comprehensive Plan. Recreation is one of the uses for Basin's water resources identified in the Compact. *See* Compact Third Whereas Clause and Article 8.

The Commission received numerous comments concerning potential harms and impacts to recreational uses in the Delaware River Basin. The comments and response related to the protection of recreational uses have appeared in other sections (especially Section 2.6.6, Economic Impacts and Section 2.3.3.2, Surface Waters and Aquatic Life). As such, no new Statements of Concern and

Responses will be provided in this section. However, examples of the paraphrased comments include the following:

- The Delaware River was designated as a national Wild and Scenic River by Congress because of its outstanding features, irreplaceable resources, exceptional water quality and scenic and recreational value.

- The Delaware River and its tributaries provide multiple recreational benefits to the surrounding area. As a natural environment, the waters provide vital habitat for trout and other recreational fish.

- The unique value of recreational assets in the Delaware River Basin is jeopardized by hydraulic fracturing and related pollution. Recreational values must be protected for the public and future generations."

As discussed in the responses in: Section 2.3.2.2, Pollution from Spills; Section 2.3.2.4, Wastewater Handling and Disposal; Section 2.3.2.5, Landscape Changes; Section 2.3.3.2, Surface Waters and Aquatic Life; and Section 2.6.6, Economic Impacts, water resources and related recreational uses can be impacted by high volume hydraulic fracturing. For reasons discussed elsewhere in this document, 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. Controlling future pollution by prohibiting such activity in the Basin is required to effectuate the Comprehensive Plan, to avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and to preserve the waters of the Basin for uses in accordance with the Comprehensive Plan, including recreational uses.

2.6.8 Agricultural Uses

Protected uses in the Comprehensive Plan include: agricultural; industrial; public water supplies after reasonable treatment (except where natural salinity precludes such uses); wildlife, fish and other aquatic life; recreation; navigation; waste assimilation (to the extent that such use is compatible with other uses); and such other uses as may be provided by the Comprehensive Plan.

STATEMENT OF CONCERN (SC-95)

Some commenters expressed concerns about the adverse impacts that HVHF might have on agriculture, while others portrayed HVHF as an opportunity for property owners, including economically strapped farmers, to supplement their income by accessing the minerals beneath their land.

THE FOLLOWING COMMENTS ARE REPRESENTATIVE OF THOSE SUPPORTING SECTION 440.3 OF THE DRAFT RULE, PROHIBITING HIGH VOLUME HYDRAULIC FRACTURING WITHIN THE BASIN:

- Various aspects of hydraulic fracturing, including chemicals and contaminants, some of them highly radioactive, which can find their way onto farmland and into livestock and food products (via runoff or migration to streams, ponds and irrigation systems, soil or groundwater) unjustifiably threaten agriculture and can cause irreparable damage, increased human health risks, and serious financial impacts. The resulting impacts can reduce crop yields, jeopardize organic farm certification, and even force families out of farming and cause a reduction in the number of farms.

- Protecting the quality and safety of agricultural food production is imperative for the health and safety of residents and to ensure consumer confidence in food products.

- Studies and case reports from across the country have found instances of deaths, neurological disorders, aborted pregnancies, and stillbirths in livestock and other farm animals that have come in contact with hydraulic fracturing-generated wastewater.

THE FOLLOWING COMMENTS ARE REPRESENTATIVE OF THOSE OPPOSING SECTION 440.3 OF THE DRAFT RULE, PROHIBITING HIGH VOLUME HYDRAULIC FRACTURING WITHIN THE BASIN:

- Farmers have participated in much of the conservation and natural gas industry infrastructure development activity on their farms, much of which is rather unobtrusive and has operated virtually without incident. Farmers need and want clean water and undertake significant expenditures to protect it, and current regulations are adequate to that task.

- Farming is increasingly difficult economically and the financial opportunities derived from natural gas drilling leases keep farming viable.

RESPONSE (R-95)

The Commission acknowledges that the effects of high volume hydraulic fracturing on water resources may affect agriculture. The Commission's focus is managing the water resources in accordance with its Comprehensive Plan for the immediate and long-range development and use of the water resources of the Basin, including, among others, agricultural uses. Because the Commission's final rule prohibits high volume hydraulic fracturing within the Basin, any effects on water resources used or potentially used for agricultural purposes are not anticipated. The Commission also recognizes that high volume hydraulic fracturing activities – and regulations for the protection of water resources from the impacts of those activities – have economic effects. Comments on the economic impacts associated with HVHF and the proposed rule are addressed in Section 2.6.6, Economic Impacts, of this response to comments.

2.6.9 Commercial and Industrial Uses

Protected uses in the Comprehensive Plan include: agricultural; industrial; public water supplies after reasonable treatment (except where natural salinity precludes such uses); wildlife, fish and other aquatic life; recreation; navigation; waste assimilation (to the extent that such use is compatible with other uses); and such other uses as may be provided by the Comprehensive Plan. The Commission did not receive any significant comments about the protection of existing industrial or commercial water uses, except as those comments were addressed in Section 2.3.2.1, Water Use and Section 2.3.3.1, Drinking Water Resources. Comments received from the Oil and Gas Industry are reflected in numerous sections and responded to throughout this Comment and Response Document.

2.6.10 Other Legal Comments

Statement of Concern (SC-96)

- No rational basis exists to prohibit HVHF. The prohibition violates substantive due process. The risks posed by inadvertent spills and releases are speculative, any human activity involves the possibility of spills, and the prohibition is disproportionate to the risks posed by inadvertent spills. Any prohibition must be based on "substantial evidence." The prohibition of HVHF, including the 300,000-gallon threshold in the definition of HVHF, is arbitrary and capricious.
- A statement by a Governor supporting the prohibition was inappropriate, created a predetermined outcome, and showed that the notice and comment process was a sham. The Commission failed to utilize science and fact-based analysis as the bases for regulatory decision making.
- A cumulative impact analysis or environmental study is needed before allowing HVHF activities in the Basin, particularly in light of environmental problems caused by HVHF throughout Pennsylvania.

Response (R-96)

The Commission disagrees with all of these comments. Contentions that a regulation is arbitrary and capricious or irrational may be construed as a substantive challenge to government action under the Due Process Clause of the Fifth Amendment to the U.S. Constitution, or as a statutory or other non-Constitutional challenge. A regulation satisfies substantive due process if it rationally furthers any legitimate governmental objective. *See*, *e.g.*, *Am. Express Travel Related Servs., Inc. v. Sidamon-Eristoff*, 669 F.3d 359, 366 (3d Cir. 2012); *Sammon v. N.J. Bd. of Med. Exam'rs*, 66 F.3d 639, 645 (3d Cir. 1995). Similarly, a regulation will survive a statutory or other non-Constitutional challenge unless a review of the administrative record shows the regulation to be arbitrary, capricious, an abuse of discretion or otherwise not in accordance with law.[64] "Agency action is not arbitrary and capricious when the agency examine[d] the relevant data and articulate[d] a satisfactory explanation for its action including a rational connection between the facts found and the choice made." *Council Tree Investors, Inc. v. Fed. Commc'ns Comm'n*, 863 F.3d 237, 240 (3d Cir. 2017) (quotation omitted).

The purpose of the regulation is to protect, conserve and manage the water resources of the Basin. *See* 18 C.F.R. § 440.1(a). More particularly, the HVHF prohibition is required to effectuate the Comprehensive Plan, avoid injury to the water resources of the Basin, protect the public health and

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[64] The Delaware River Basin Compact is silent regarding the standard of review applicable to Commission regulations, and courts have expressed uncertainty as to whether a "substantial evidence" standard should apply in appeals of adjudications. *See, e.g., Del. Water Emergency Group v. Hansler*, 536 F. Supp. 26 (E.D. Pa. 1981). Although Compact Section 15.1(m) exempts the Commission from the Administrative Procedure Act ("APA"), in this context the APA provides a useful reference. *See id.* at 36. Under the APA, the substantial evidence standard applies when formal rulemaking hearings are conducted under Sections 556 and 557 of the APA. *See* 5 U.S.C. § 706(2)(E). The present process followed standard notice and comment rulemaking procedures, not the hearing procedures under Sections 556 and 557. The arbitrary and capricious standard applicable under the APA, 5 U.S.C. § 706(2)(A), to notice and comment rulemaking by analogy is the appropriate standard in the present context.

preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. *See* 18 C.F.R. § 440.3(a). As discussed in the response to comments concerning the Commission's statutory authority (*see* Section 2.1.1 of this Comment and Response Document), this clearly legitimate objective is consistent with the purpose for which the Commission was established and its various powers granted by the Compact. *See also,* Delaware River Basin Compact ("Compact"), §§ 3.1, 13.1. The remaining question is whether the prohibition would reasonably further this objective.

HVHF creates substantial risks, vulnerabilities and impacts to the quality of surface and groundwater resources. *See* Sections 2.3.2, 2.3.3 and 2.3.4 of this Comment and Response Document. To evaluate these risks, vulnerabilities and impacts in relation to the Comprehensive Plan, the Commission staff, assisted by staff of the signatory party agencies, undertook a scientific and technical analysis. They considered applicable scientific literature and data, evaluated the studies and data compiled by Commission member agencies and other government agencies, examined HVHF activities outside the Basin, conducted six public hearings, reviewed thousands of public comments and considered options for exercising their policy discretion. *See*, *e.g.*, Section 2.3.1 (Basis and Background Documents), Reference List, Section 1.2 (Public Input Purpose and Process), and Section 1.3 (Overview of Comment Submissions) of this Comment and Response Document. Based on their review and evaluation of this analysis and the conclusions and recommendations of Commission staff, the Commissioners determined that the immediate and long-term risks to the quality and quantity of water resources of the Basin, including its Special Protection Waters, are sufficiently severe to warrant prohibiting HVHF activities in the Basin to achieve the purpose noted above. *See* 18 C.F.R. § 440.3(a). As shown throughout this Comment and Response Document, in light of the multiple ways HVHF would significantly and adversely impact water resources, any less stringent requirements imposed on HVHF in the Basin would not sufficiently protect the Basin's water resources.

The 300,000-gallon threshold defining HVHF as set forth in Section 440.2 of the regulation is not arbitrary. In the Commission's professional judgment, the risks to water resources increase significantly at the 300,000-gallon threshold and above. This threshold is similar to the threshold established by New York State, a party to the Compact. The basis for the Commission's adoption of the threshold is set forth in Section 2.2 (Definitions) of this Comment and Response Document (Response R-10).

During the rulemaking process, after the proposed regulation was published and public comments were received and reviewed, certain Governors noted their continued support for a HVHF prohibition. No Commissioner made a final decision until all comments and proposed responses thereto were reviewed and analyzed, and the Commission voted to adopt the regulation at a public meeting. Due process does not require elected officials to remain silent during the rulemaking process.

Sufficient grounds now exist to impose the HVHF prohibition. The Commission considered the known and potential individual and cumulative effects of the hydraulic fracturing of numerous wells and the likely associated impacts resulting from spills, releases, discharges and migration of the hundreds of chemicals in fracturing fluids and production wastewaters. The information and analysis upon which the regulation is based has been carefully evaluated and is sufficient to support the regulation.

STATEMENT OF CONCERN (SC-97)

- The prohibition of HVHF within the Basin violates the Equal Protection Clause of the U.S. Constitution because there is no rational basis to treat the oil and gas industry differently from other industries operating in the Basin. Potential spills from other industrial operations pose at least as much risk to water resources as potential spills from HVHF. A Commission risk assessment of the chemicals at issue is necessary.

- Prohibiting HVHF activities in the Basin while allowing similar activities in the Susquehanna River Basin violates the Equal Protection Clause.

RESPONSE (R-97)

The Commission disagrees with these comments. As the commenters acknowledge, the standard applicable to Equal Protection[65] challenges to the Commission's prohibition of HVHF activities in the Basin is whether classifying HVHF activities differently from other industrial activities bears a rational relation to a legitimate governmental purpose. *See*, *e.g.*, MSC, 2018, p. 28 (leg.), citing *Regan v. Taxation with Representation of Washington*, 461 U.S. 540, 547 (1983). Here, the governmental purpose is to protect, conserve and manage the quality and quantity of the water resources of the Basin. *See* 18 C.F.R. § 440.1(a). More particularly, the HVHF prohibition is required to effectuate the Comprehensive Plan, avoid injury to the water resources of the Basin, protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. *See* 18 C.F.R. § 440.3(a). This purpose is legitimate, is authorized by the Compact, and furthers the Commission's statutory goals. *See*, *e.g.*, Compact, §§ 3.1, 3.2(a) and (b), 3.6(b) and (h), 4.1, 5.2, 7.1, 13.1 and 14.2(a). *See also*, Section 2.1.1 (Statutory Authority) of this Comment and Response Document. The remaining question is whether classifying HVHF projects differently than other projects bears a rational relation to this purpose.

As an initial matter, the Commission rejects the premise of certain comments that the oil and gas industry as a whole is being singled out for differential treatment by these rules. The HVHF regulation is narrowly tailored and applies to only one specialized method used by an industry that employs a variety of drilling and extraction techniques and methods. The Commission's focus is on the activities posing significant risks to water resources, not the oil and gas industry in general.

In addition, as more fully described in Section 2.3.2.1 (Water Use) of this Comment and Response Document, unlike other activities in the Basin including other oil and gas extraction methods and techniques, HVHF involves the injection of fracturing fluid—a mixture of chemicals and water which can exceed 16 million gallons—at high pressure into a well bore that penetrates groundwater, including drinking water aquifers. The Commission is unaware of any other industry that creates

[65] Equal protection principles derived from the Equal Protection Clause in the 14th Amendment to the U.S. Constitution, applicable to the states, have been applied to the federal government through the Due Process Clause of the Fifth Amendment. In this response, the Commission assumes *arguendo* that equal protection principles likewise apply to DRBC, a federal-interstate compact agency.

mixtures of water and toxic compounds in this large quantity, and that as part of its production processes, injects this mixture through drinking water aquifers into the subsurface.

Once injected, the fracturing fluid mixes with naturally occurring radioactive material ("NORM") and other contaminants in the shale formation. Much of the water used stays in the ground and is completely removed from the hydrologic cycle. *See* Section 2.3.2.1 of this Comment and Response Document. The remaining large quantity of contaminated fracturing fluids together with formation liquids return to the surface as wastewater. The wastewater return flow is managed on or near the well pad site until the captured wastewater is sent off-site for recycling and reuse or for disposal. HVHF is unique in that it involves the injection of millions of gallons of water and chemicals into the ground, penetrates aquifers, uses almost all of its water consumptively,[66] and creates millions of gallons of toxic wastewater that cannot be safely discharged into the waters of the Basin. *See* Sections 2.3.2.2 (Pollution from Spills) and 2.3.2.4 (Pollution from Wastewater Treatment and Disposal) of this Comment and Response Document.

The HVHF activities described above pose complex uncontrollable risks to water resources distinct from risks posed by other types of activities that may occur in the Basin. Spills of some of the thousands of gallons of undiluted chemicals and millions of gallons of fracturing fluids stored, handled and utilized at a well pad site would cause pollution of streams and groundwater. Because HVHF production wastewater returning to the surface includes fracturing fluids mixed with formation water containing NORM and other contaminants from the shale formation, spills of production wastewater may be even more toxic than spills of fracturing fluids.[67]

If HVHF activities were undertaken in the Basin, spills and releases would also occur subsurface. Some failures of casing and cementing of the well bore would result in releases of fracturing fluids or production wastewaters, some of which would migrate into groundwater and drinking water aquifers.[68] Unconfined fracturing fluids injected into the shale formation, formation waters, and methane that do not return to the surface through the well bore pose additional risks of contamination, as these contaminants may migrate through fractures or other pathways and adversely impact surface waters and aquifers. *See generally* Section 2.3.2.3 of this Comment and Response Document. Other industries do not abandon large quantities of wastewater in the ground without the geologic and other controls deployed at permitted underground injection control sites.[69]

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[66] *See* 18 C.F.R. 420.1 where the Commission defines "consumptive use" in relevant part as "any . . . water use for which the water withdrawn is not returned to the surface waters of the basin undiminished in quantity."

[67] *See* Sections 2.3.2.2 through 2.3.2.4 and 2.3.3 of this Comment and Response Document for discussion of the risks of harm to public health and water resources and the impacts to public health and water resources that have occurred from discharges of fracturing fluids and production wastewater in other jurisdictions.

[68] *See* Section 2.3.2.3 of this Comment and Response Document for a detailed discussion of risks to water resources associated with subsurface migration of fluid, gas and other contaminants via natural and artificial pathways.

[69] At least one peer-reviewed study suggests that even the controls used at these highly regulated underground injection control sites may not be protective. *See* Sections 2.3.3.1, 2.3.3.2 and 2.6.1 of this Comment and Response Document, *citing* Kassotis *et al.,* 2016 (documenting endocrine disrupting activities of surface water associated with a West Virginia oil and gas industry wastewater disposal site).

In addition, if permitted in the Basin and economical to undertake, HVHF activities would occur in sensitive headwater areas within the drainage area to waters the Commission has designated as Special Protection Waters ("SPWs"), where few industrial operations are presently located. Existing Commission regulations prohibit measurable adverse change to the quality of SPWs. Basin Regulations—Water Code, § 3.10.3A.2. The potential for industrial HVHF-related activities to be dispersed throughout the drainage area to SPWs poses significant risks to water quality in this protected area.

In light of the differences in the nature of the activities and the risks posed discussed above, the Commission may regulate HVHF differently from other activities.[70]

In addition, because unlike ongoing industrial activities, HVHF would be new to the Basin, the prohibition of HVHF may encourage the development and deployment of safer technologies for extracting natural gas. The Commission has acted before the millions of dollars in capital expenditures necessary to construct well pads and install natural gas wells for HVHF have been made, and in doing so has prevented reliance on HVHF and its associated infrastructure.

Moreover, the prohibition of HVHF would conserve the water resources of the Basin by, among other things, preventing consumptive water use. The potential consumptive use of millions of gallons of water removed from sensitive headwaters areas within the drainage area to SPWs distinguishes HVHF from most existing industrial activities. Although other industries pose a threat of pollution or use some water consumptively, none present combined risks that are as severe as those posed by HVHF.

An Equal Protection argument founded on the difference between the Commission's regulatory approach within the Delaware River Basin and a separate approach taken by other authorities in the Susquehanna River Basin is without merit. An equal protection issue does not arise where different regulators with separate jurisdictional authorities use their own approaches to address HVHF activities in river basins with different geological characteristics and different water resource uses and needs. *See* Sections 2.3.2.3 (Pollution from Gas and Fluid Migration) and 2.3.2.1 (Water Use) of this Comment and Response Document. Based on the foregoing, classifying HVHF differently than other Basin activities is a rational choice.

STATEMENT OF CONCERN (SC-98)

The Pennsylvania Constitution requires the Commission to protect Citizens' rights to clean air and clean water.

[70] The Commission may address the substantial risks to water resources from HVHF through regulation, whether or not other activities in the Basin also pose some risks. The Commission may take a step-by-step approach to minimizing risks from any industry—especially one that is introducing a technique new to the region—even if the risks presented by the subject industry were equivalent to existing industrial risks not yet addressed. But in the case of HVHF, the risks are more severe than those posed by other industries.

Response (R-98)

Article I, § 27 of the Pennsylvania Constitution, the Environmental Rights Amendment, recognizes and protects the Commonwealth citizens' "right to clean air, pure water and to the preservation of the natural, scenic, historical and esthetic values of the environment." The Pennsylvania Supreme Court has affirmed this right. *See*, *e.g.*, *Pennsylvania Envt'l Def. Fund v. Commonwealth*, 161 A. 3d 911(Pa. 2017); *Robinson Twp. v. Commonwealth*, 83 A. 3d 901 (Pa. 2013). As the Pennsylvania Supreme Court explained, Article I, § 27 was designed in part to prevent the reoccurrence of environmental injuries caused by historic exploitation of timber and coal in the Commonwealth. *Id*. The Commission has concluded that HVHF has the potential to cause similar injuries to the water resources of the Basin.

Although Article I, § 27 of the Pennsylvania Constitution and the Compact have overlapping goals, as a federal-interstate compact agency, the Commission is not bound by, nor is it empowered to carry out, state constitutional provisions. While the prohibition of HVHF is consistent with Article I, § 27 of the Pennsylvania Constitution, the Commission has acted pursuant to the authority granted by the Compact, not pursuant to the Pennsylvania Constitution.

Statement of Concern (SC-99)

The proposed prohibition of high-volume hydraulic fracturing in the Basin would effectuate a taking of property requiring just compensation under the Fifth Amendment to the United States Constitution.

Response (R-99)

The Takings Clause of the Fifth Amendment to the United States Constitution, made applicable to the states by the Fourteenth Amendment, prohibits the government from taking private property for public use without just compensation. Regulatory takings are classified as categorical when they "completely deprive an owner of 'all economically beneficial us[e] of her property.'" *Lucas v. S.C. Coastal Council,* 505 U.S. 1003, 1019 (1992) (emphasis in original). Otherwise, they are evaluated under an ad hoc balancing test. *See, e.g., Murr v. Wisconsin,* 137 S. Ct. 1933 (2017); *Lingle v. Chevron U.S.A. Inc.,* 544 U.S. 528, 538 (2005); *Tahoe-Sierra Preservation Council, Inc. v. Tahoe Regional Planning Agency,* 535 U.S. 302 (2002); *Penn Cent. Transp. Co. v. New York City,* 438 U.S. 104, 122 (1978) (*"Penn Central"*). Takings analysis may be highly fact sensitive.

As explained below, because the prohibition of high-volume hydraulic fracturing adopted by DRBC would not deprive any person of all economic value in their property, it is not a categorical taking. In addition, considering relevant factors, including but not limited to the remaining value of the property, the absence of reasonable investment-backed expectations, and the importance to the public of protecting the water resources of the Basin, when evaluated under a balancing test, the prohibition does not effectuate a taking of property. As such, no compensation is required.

The proposed HVHF prohibition does not effectuate a categorical taking.

Certain commenters contend that the HVHF prohibition would totally deprive persons holding a property interest in only natural gas in the subsurface, including lessees[71] of natural gas interests and persons who own only a mineral estate, of all economically beneficial use of their properties and effectuate a categorical taking. *See, e.g.,* MSC, 2018, p. 22. (leg.). No commenter has offered an estimate of the number of persons in the Basin owning solely these limited rights. The Commission disagrees with these commenters.

Here, the entire bundle of fee simple property rights is the proper unit of analysis and cannot properly be divided for purposes of a takings analysis. Surface and mineral estates are contiguous, and natural gas extraction requires construction and operation of facilities such as a well pad and wastewater tanks in addition to other activities on the land surface. States regulate HVHF activities conducted both above and below the surface together. The HVHF prohibition benefits the surface estate which can continue to be used for various revenue producing purposes and retains economic value.[72]

Even if the gas leasehold or mineral estate alone were the proper unit of analysis, which it is not, that unit of property retains economic value.[73] The mineral rights owner may extract natural gas now

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[71] In July 2013, citing low natural gas prices and declaring a *force majeure* event, Newfield Appalachia PA LLC and Hess Corp. terminated approximately 1,500 gas leases covering more than 100,000 acres in Wayne and Susquehanna Counties. *See* https://stateimpact.npr.org/pennsylvania/2013/07/16/newfield-exploration-says-low-natural-gas-prices-led-to-wayne-county-lease-terminations/; https://www.naturalgasintel.com/articles/print/5058-newfield-hess-terminate-leases-in-northeast-pennsylvania. As a result, the Commission anticipates that there are few, if any, outstanding natural gas leases in the Basin. In addition, where a fee simple owner has no valid takings claim, it cannot create a valid claim by leasing or conveying mineral rights to others. *See*, *e.g.*, *Murr*, 137 S. Ct. at 1953 (Roberts, C.J. dissenting) (explaining courts are to "detect and disarm" "strategic unbundling" of property rights or "gamesmanship" by landowners and States in "an attempt to create a takings-specific definition of 'private property.'").

[72] The cases cited by commenters do not require a different result. *Whitney Benefits v. United States,* 926 F.2d 1169 (Fed. Cir. 1991), pre-dates the Supreme Court's holding in *Lucas*. With the exception of one Fifth Circuit case, *Vulcan Materials Co. v. City of Tehuacana*, 369 F.3d 882 (5th Cir. 2004), decided under Texas law, commenters have not cited and the Commission is not aware of any post-*Lucas* decision in which any federal court has found a categorical taking with respect to a property interest less than fee simple. In *Vulcan Materials*, the city adopted an ordinance specifically "to completely prohibit Vulcan from engaging in [limestone] mining" within city limits. *Id*. at 887. Unlike DRBC's prohibition of HVHF, the ordinance was not limited to a single extraction method. Moreover, despite the complete deprivation of property rights, the Fifth Circuit remanded the case to the district court to determine whether the prohibited activity might constitute a nuisance. Here, the prohibition applies only to HVHF, and use of that technique in the largely rural drainage area of Special Protection Waters in the Basin would likely cause measurable adverse change to the quality of groundwater resources upon which this region depends, as well as to the Commission's Special Protection Waters. Particularly in light of the region's geology, the use of HVHF in this region would simultaneously impair drinking water and aquatic species habitat in violation of existing DRBC regulations and, in light of this and other adverse impacts, create a nuisance.

[73] For purposes of this analysis, DRBC assumes *arguendo* that each property owner can demonstrate on a case-by-case basis that natural gas is present on its mineral estate or leasehold and can be economically recovered. *See*, *e.g.*, *Marion & Rye Valley Ry. Co. v. United States*, 270 U.S. 280, 282 (1926) (no recovery under Fifth

employing technologies other than HVHF, or may leave any natural gas in the ground for future extraction using these existing or future technologies. And any other minerals in which the owner holds an interest may be extracted now or in the future.

In addition, as shown throughout this Comment and Response Document, in light of the geology of the Basin, the risks, vulnerabilities and impacts from hydraulic fracturing if allowed in the Basin preclude HVHF under background principles of nuisance and property law restricting the owner's intended use of the property. *See, e.g., Murr,* 137 S. Ct. at 1943; *Lucas,* 505 U.S. at 1029. These impacts include, among others described in this Comment and Response Document, harm to drinking water sources on which over 13 million Basin residents depend.

In sum, the HVHF regulation does not effectuate a categorical taking.

The proposed HVHF prohibition does not effectuate a regulatory taking under a multifactor balancing analysis.

Commenters further contend that the HVHF prohibition would effectuate a regulatory taking of property of those landowners who own fee simple interests, an ownership right which includes both the surface and mineral estates associated with a particular parcel in the Basin. Because the surface rights would clearly retain value following implementation of an HVHF prohibition, a balancing test would apply (unless, as noted above, the nuisance exception precludes a regulatory taking claim).

Although this record does not contain information on the specific circumstances of each property owner, several considerations have broad application. Comparing the post-deprivation value to pre-deprivation value, the economic effect of the governmental action on the property owner would not be severe. The parcel as a whole retains a significant portion of its economic value notwithstanding the HVHF prohibition. For example, the surface rights may be used for any lawful purpose, including residential, commercial, agricultural and other uses. And any economically recoverable natural gas present on a property may be extracted now or in the future using technologies other than HVHF.

At the time they acquired their properties, many if not all property owners had no investment-backed expectations in the extraction of natural gas from tight shale formations, or their expectations were or should have been tempered by the anticipation of regulation potentially including a prohibition of HVHF. Because natural gas exploration and production is a highly regulated activity, any property owners who contemplated extraction of natural gas should reasonably have expected that their activities would be subject to regulation that may become increasingly stringent. Moreover, shortly after HVHF and horizontal drilling technologies became available to economically extract natural gas from some tight shale formations in certain circumstances, the Commission notified the public of the likelihood that it would issue a regulation. *See, e.g.,* https://www.nj.gov/drbc/library/documents/EDD5-19-09.pdf; https://www.nj.gov/drbc/library/documents/5-05-10_minutes.pdf.

As discussed throughout this Comment and Response Document, the Commission's action is designed to protect, conserve and manage the water resources of the Basin by avoiding the harmful

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Amendment when "nothing of value" is taken from the property owner). This is a fact-intensive inquiry incapable of resolution on this rulemaking record.

impacts HVHF activities would likely cause. The Commission conducted a thorough evaluation of the potential impacts of unconventional natural gas development on the water resources of the Basin. The Commission reviewed and in part relied upon the exhaustive studies by the New York State Department of Environmental Conservation Final Supplemental Generic Environmental Impact Statement ("SGEIS") and the June 2015 Findings Statement which was based in part on the December 2014 New York State Department of Health Public Health Review, the 2016 United States Environmental Protection Agency study on the impact of HVHF on drinking water resources, and other data and studies, some of which were cited in the thousands of public comments submitted in connection with the current rulemaking. The public interest embodied in the Compact and furthered by the Commission's regulations designed to protect water resources upon which the public and businesses rely weighs heavily against the assertion of certain commenters that the HVHF prohibition requires DRBC to compensate landowners.[74]

A balance of the factors and other legal considerations, including those discussed above, demonstrate that the Commission's regulations have not effectuated a regulatory taking.

Statement of Concern (SC-100)

The DRBC is a federal agency subject to the requirements of NEPA. DRBC must prepare an EIS evaluating the range of potential adverse environmental impacts of its proposed regulatory program before issuing new regulations governing natural gas development within the Basin.

Response (R-100)

The DRBC is a federal-interstate agency distinct from an agency of the federal government. DRBC is not subject to the National Environmental Policy Act of 1969 ("NEPA"), 42 U.S.C. §§ 4321-4347, which is applicable only to "agencies of the Federal Government."[75] 42 U.S.C. § 4332. Nevertheless, consistent with the policies underlying NEPA, DRBC carefully examined the potential water resource impacts from HVHF, solicited and thoroughly examined public comments and adopted a prohibition on HVHF activities to eliminate adverse impacts to water resources.

NEPA requires a federal agency planning to undertake a major federal action to evaluate that action's impact on the human environment, 42 U.S.C. § 4332, and inform the public that it has considered

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[74] The absence of any physical invasion of property likewise is a factor which supports a finding that no compensable regulatory taking has occurred. *See, e.g.*, *Penn Central*, 438 U.S. at 124. In addition, the background principles of nuisance and property law discussed above which restrict HVHF activities in the Basin apply equally to owners of fee simple interests and owners of only mineral interests.

[75] Whether the Commission is a federal agency subject to NEPA was discussed in *State of New York v. U.S. Army Corps of Engineers*, 896 F. Supp. 2d 180 (E.D.N.Y. 2012), and related actions. The Court dismissed the lawsuits on grounds of lack of standing and ripeness, and in light of the absence of subject matter jurisdiction, did not resolve the merits of the arguments. *See also* cases discussed in the next footnote below. One related question is whether NEPA can be enforced through a cause of action other than the Administrative Procedure Act ("APA"). The APA does not apply to the Commission, Compact §15.1(m), and no other cause of action may exist to bring a NEPA claim against the Commission. DRBC has considered the comment raising NEPA grounds without prejudice to DRBC's right to defend any NEPA claim against it on any ground.

environmental concerns in its decision-making process. *See*, *e.g.*, *Balt. Gas & Electric Co. v. NRDC*, 462 U.S. 87 (1983). For every major federal action significantly affecting the quality of the human environment, a federal agency must prepare an environmental impact statement ("EIS") that reviews the significant environmental impacts of the proposed action and informs decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment. 40 C.F.R. § 1502.1.

DRBC is not an "agency of the federal government" within the meaning of NEPA nor a "federal agency" as defined in NEPA's implementing regulations promulgated by the White House Council on Environmental Quality, 40 C.F.R. § 1508.1(k). For this reason, DRBC is not subject to NEPA's requirements. NEPA does not mention federal-interstate agencies in general or the DRBC in particular in the text of the statute or in its legislative history. The Compact creating a "federal-interstate compact agency" enacted a new experiment in cooperative federalism that had its origins in an advisory committee comprised of representatives of the states and two municipalities, not the federal government or the Congress.

When Congress creates a federal agency, all existing and future laws generally applicable to federal agencies apply to the new federal agency unless Congress specifies otherwise. When Congress consented to the Compact pursuant to Art. I, Sec. 10 of the U.S. Constitution, however, it specified which federal laws applicable to federal agencies apply to the Commission and which do not apply. Because Congress consented to a new form of entity to which then-existing laws pertaining to federal agencies did not automatically apply, laws applicable to federal agencies enacted after the Compact likewise do not automatically apply to the Commission.

In addition, when enacting the Compact, Congress chose not to endow the Commission with the several characteristics inherent in agencies of the federal government. First, the President does not control the Commission, nor are a majority of the Commissioners federally appointed. Instead, the Compact grants each of the signatory parties one vote, and four of the five Commissioners are the governors of the four basin states over whom the President has no authority or control. Second, the federal government does not control the Commission through financial appropriations. The Commission is not subject to the financial requirements imposed on federal agencies, and in only one federal fiscal year since 1996 has the federal government appropriated monies to the Commission in payment of its "fair share" contribution to the Commission's budget. Compact, § 13.3.

Third, unlike officers and employees of federal agencies, the Commission's officers and employees are not federal employees. *See* Compact, § 15.1(n). Fourth, the Commission is expressly not a federal agency for purposes of various federal statutes, including the Administrative Procedure Act. Compact, § 15.1(m). Fifth, when Congress wanted certain laws applicable to federal agencies to also apply to the Commission, Congress so specified. Compact, § 15.1(i)-(j). Sixth, the Commission has regional, not national, jurisdiction and is not subject to congressional supervision.[76] *See also*, *Hess v. Port*

[76] In addition, courts have not treated DRBC as a federal agency. *See M&M Stone Co. v. Pennsylvania*, No. 07-cv-04784, 2008 U.S. Dist. LEXIS 76050 (E.D. Pa. Sept. 29, 2008) ("Defendant Commission is not an arm of the federal government."); *Borough of Morrisville v. DRBC*, 399 F. Supp. 469 (E.D. Pa. 1975) (describing the Commission as "neither wholly a federal agency nor a state one. It is a body on which both the federal government and each of the four states through whose territory the Delaware River runs are equally represented."); *Delaware Water*

Authority Trans-Hudson Corp., 513 U.S. 30 (1994), (holding that an interstate compact agency is not protected by the Eleventh Amendment because it is distinct from the sovereigns creating it).[77]

Although DRBC is not bound by NEPA or its implementing regulations, here the process DRBC followed serves as the functional equivalent of the NEPA process. DRBC provided full public notice of its proposed regulations and conducted an extensive public process. Public comments were reviewed by the Commission and responses provided. DRBC also performed a technical and scientific analysis of the risks and potential impacts to water resources and the environment if HVHF activities were to occur in the Basin. Other portions of this Comment and Response Document detail the public process and the technical and scientific review performed. *See* Sections 1.2.2 and References. As this Comment and Response Document discusses, unlike other regulatory options, the prohibition adopted by DRBC will have no significant adverse impact on human health or the environment.

2.6.11 Public Input Process

Statement of Concern (SC-101)

Commenters stated that the public comment period should have been longer.

Response (R-101)

Several commenters suggested that the original 90-day public comment period was inadequate considering the topic and that the comment period extended over the December holiday season. Several commenters requested a 180-day comment period.

The comment period was extended to 120 days from November 30, 2017 to March 30, 2018. The comment period produced 8,679 on-line comment submissions and 223 oral comments at six public hearings. The 120-day comment period was adequate to collect input on this matter.

Statement of Concern (SC-102)

Commenters stated that there should have been more public hearings.

Emergency Group v. Hansler, 536 F. Supp. 26 (E.D. Pa. 1981), *aff'd*, 681 F.2d 805 (3d Cir. 1982) ("That DRBC is a federal agency for purposes of NEPA is very doubtful. . . . The Commission, formed by compact among four states and the United States Government as co-equal members, would not appear to be a federal agency, nor would actions of DRBC appear to be 'Federal.'").

[77] The Commission recognizes that certain language in the Compact appears to be in conflict with the language upon which the Commission relies. In particular, Compact § 15.1(o) provides: "Neither the Compact nor this Act shall be deemed to enlarge the authority of any Federal agency other than the commission." And the Commission is an agency and instrumentality of each of the signatory parties. *See* Compact § 2.1 and § 15.1(s)(1). But because the Commission is simultaneously an agency of the federal government and each of the basin states, *Hess* makes clear that an agency (like the Commission) composed of multiple sovereigns should be viewed as distinct from the sovereigns creating it.

Response (R-102)

Originally four public hearings were planned – two in Waymart, Wayne County, Pennsylvania and two in Philadelphia, Pennsylvania. Several commenters requested that more hearings be held including at least one in every Basin state and in New York City. There were also comments related to concern about travel times to selected locations.

Two additional hearings were added to the process. One additional hearing was held at Lehigh Carbon Community College in Schnecksville, Lehigh County, PA and one hearing was added as a toll-free telephonic hearing. The toll-free telephonic hearing provided a travel free option for anyone who wanted to make oral comments. Only two of the hearings were near capacity in terms of speaking opportunities – hearing #1 in Waymart, PA and hearing #3 in Philadelphia, PA. All other hearings including the two additional hearings were not near capacity and some ended early due to lack of additional comments. At every hearing, anyone who wanted to speak was provided that opportunity. In some cases, individuals provided input at multiple hearings.

The final number of hearings (six) and hearing locations provided ample opportunity for oral input and comment. The telephonic hearing provided another opportunity for those who did not want to travel or could not travel to provide input in a public setting. All comments were made available to the public on the DRBC's web page after the comment period closed.

Statement of Concern (SC-103)

Commenters stated that the on-line comment system was too restrictive and unfair. Several commenters suggested that the online system should have been supplemented with an avenue that allowed the public to submit written comments by email, fax, postal mail service and hand delivery. E-mail was highlighted with a quick and easy way to submit comments.

Response (R-103)

While access to the web is not universal it is certainly near universal to anyone who has e-mail. The on-line form was simple to use and allowed for uploading of large attachments as well. The system was not restrictive as evidenced by the numbers of individuals who used the system (over 8,000). Unlike e-mail, the on-line system allowed for clear tracking of comments, their location of origin and allowed the DRBC staff to minimize time needed to re-input comments into the system. In addition, a process was provided to allow those who did not have access to the internet the opportunity to request an exemption from submitting comments on-line. All request for exemptions were approved. Finally, if someone did not have access to the internet, there were ample opportunities to comment at a public hearing or over the telephone using a toll-free number. The on-line system was efficient, effective, fair and adequate for input of public comments.

Statement of Concern (SC-104)

Commenters stated that there was a charge for parking at the Philadelphia hearings.

Response (R-104)

There were no charges for parking at the Philadelphia hearings. DRBC coordinated with the hotel to leave the gates open for people who attended the public hearing to allow them to leave the parking area without charge.

Statement of Concern (SC-105)

Commenters stated that the telephone hearing was a unique and creative way to solicit public input. Commenters appreciated the phone hearing but suggested that it not replace in person hearings.

Response (R-105)

We agree that the toll-free phone hearing was valuable in supplementing the in-person hearings and providing additional opportunities for oral comment and public input without travel. While no decisions have been made about using this format in the future, it is likely that it will be considered in the future as needed to supplement rather than replace in person hearings. As technology advances, government agencies should continue to find ways to seek input through technology rather than travel.

Statement of Concern (SC-106)

Some commenters stated that the DRBC Commissioners' decision to ban fracking is politically motivated and predetermined, that the public was excluded from the decision-making process, and that the public participation process on the HVHF proposed regulations, including hearings and a written comment period, was a sham.

Response (R-106)

All Commission rulemaking decisions are made by a majority vote of the Commissioners (i.e., at least three votes in favor) at a public meeting. The Commissioners are the governors of the four member states and, on behalf of the United States, the commander of the North Atlantic Division, Army Corps of Engineers. It is common for decision-makers and elected officials to discuss their positions publicly. However, the Commissioners' positions on issues and direction to the DRBC staff may change based on the latest and best science and data available. The Commissioners conducted an extensive public input plan that provided numerous and valuable comments. The Commissioners made their final decision on the proposed HVHF regulations only after all comments were carefully considered and a detailed comment response document was prepared. The Commissioners considered, among other things, input from the public hearings and thousands of written comments, including the additional data, information and science submitted, when they voted to adopt final regulations.

2.6.12 Compliance and Enforcement

STATEMENT OF CONCERN (SC -107)

Numerous commenters expressed concern over the number of environmental violations that have occurred in Pennsylvania as the result of HVHF and related activities, averring that these violations are evidence of known and potential risks to water resources and the environment. Commenters at times presented violations data to support their positions. The data that were provided in various comment submissions are not "normalized" in any way or comparable between comments, so they are not provided in detail herein.

Other commenters representing the oil and gas industry also reviewed violations data and suggested that the industry employs best practices, follows state and federal regulations and has a good compliance record. The Marcellus Shale Coalition (MSC) stated that: "With an environmental compliance rate of nearly 97 percent operating under some of the most stringent and rigorous environmental standards in the nation, Pennsylvania's unconventional shale gas industry has a demonstrated track record of operating in a manner that protects our shared environment."

RESPONSE (R-107)

The DRBC staff analyzed compliance data from the publicly available PADEP Oil and Gas Compliance reports. The available data were limited to:

- The period of 2008 to 2018 (eleven years).
- Unconventional wells only, as defined by PADEP (those that use HVHF).
- Environmental Health and Safety violations only as defined by PADEP (administrative violations were not included).

This response is focused on the data set for all environmental health and safety violations. In other sections of this document, violations data are provided for specific water resource related impacts, such as Clean Streams Law violations and well integrity violations.

Over the eleven-year period ending in 2018 there were 4,982 Environmental Health and Safety violations issued to unconventional well drilling operators or owners by the PADEP. Figure 19 shows the number of violations reported each calendar year (the blue bars) in comparison to the number of new unconventional well spuds (the process of beginning to drill a well). From 2008 until about 2015 the annual number of violations generally followed the trends of the annual new well development activity. When new well spuds increased so did reported violated and vice versa. Since 2015, the number of new well spuds has remained relatively stable; however, environmental health and safety violations have increased significantly. The highest reported number of violations in any calendar year was 1,002, reported in calendar year 2018. The PADEP has indicated that during this time period in 2017, the PADEP began recording ongoing uncorrected violations in a manner that accounted for the second inspection as a second violation. Figure 20 shows that over the same time period, the total annual number of violations (the blue bars) have generally increased along with the total number of unconventional wells active in the Commonwealth in any given year which could also explain some of the increase in violations.

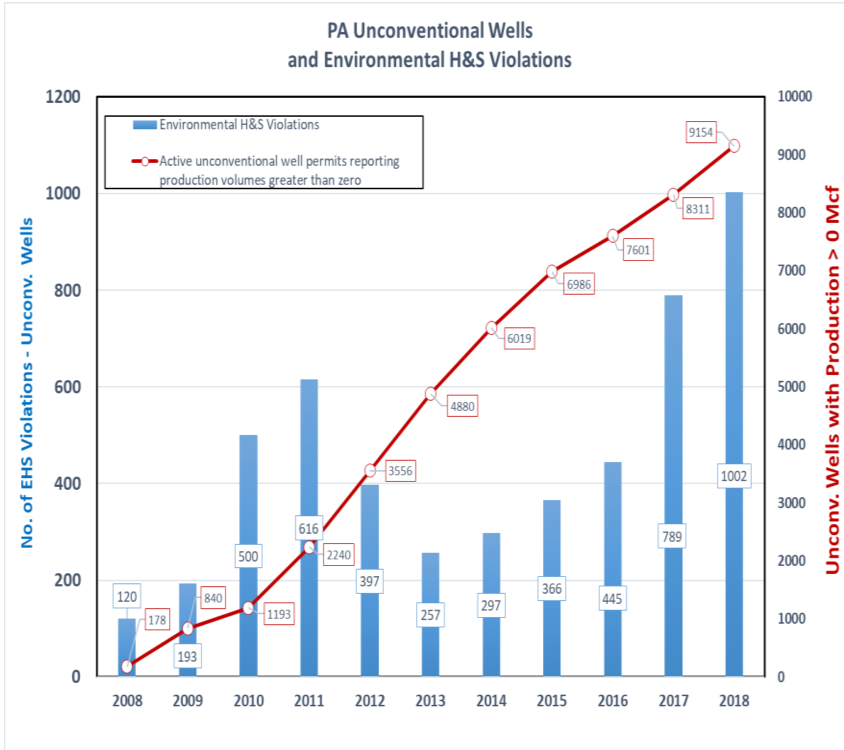

Figure 19: Yearly Violations Compared to Active Number of Unconventional Well Permits

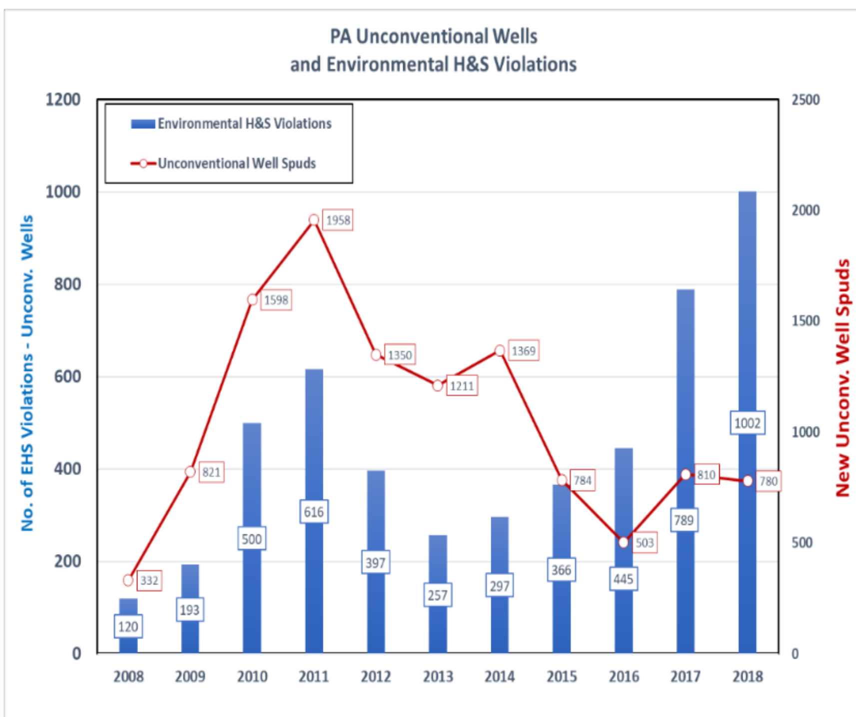

Figure 20: Yearly Violations Compared to Number of New Unconventional Wells

Figure 21 shows the same data set for the number of reported violations each year (the blue bars) as compared to the number of inspections performed each year. As noted, beginning in 2015, the annual number of violations reported has shown a steady increasing trend year over year and that trend appears to correlate to the increasing number of inspections conducted each year. Calendar year 2018 had both the highest number of inspections (18,838) and the highest number of reported violations (1,002).

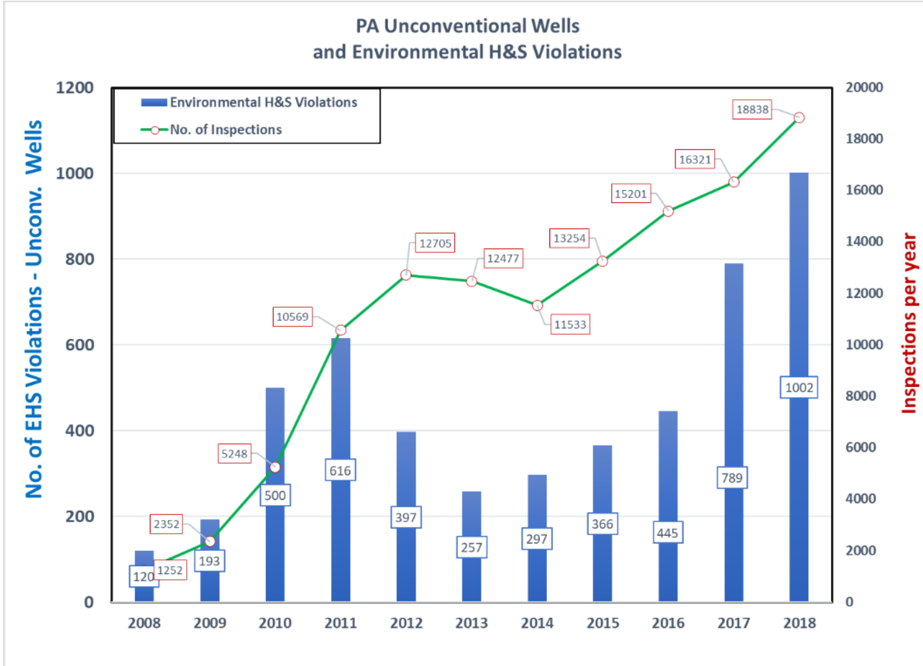

Figure 21: Yearly Violations Compared to Number of Inspections Performed Per Year

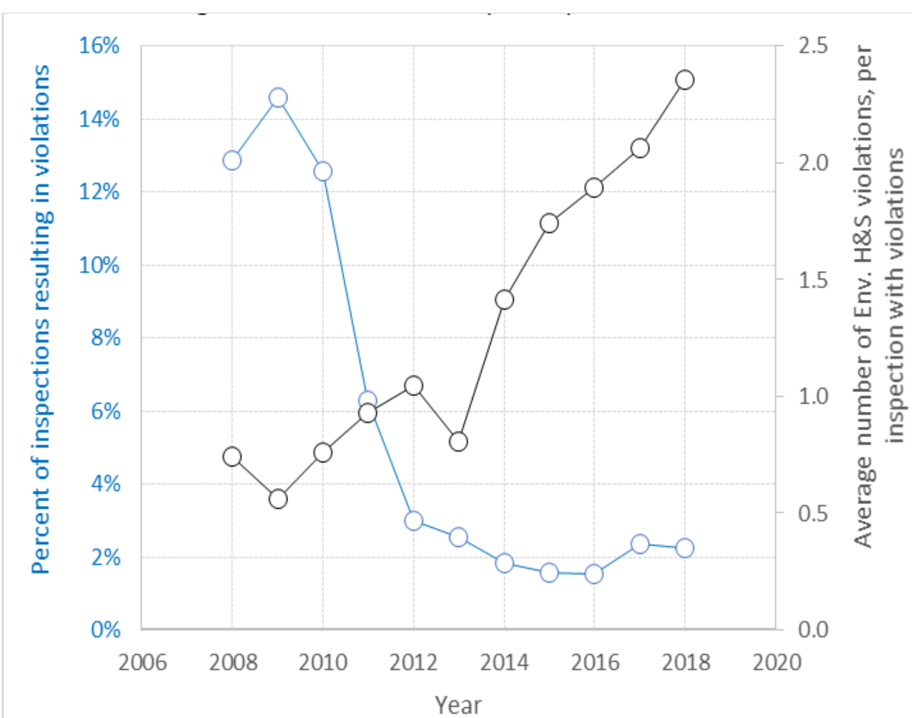

Figure 22: Rate of Inspections Resulting in Violations Compared to Average Number of Violations Per Inspection with Violations

Figure 22 shows the annual rate (percentage) of inspections resulting in violations compared to the average number of violations per inspection. Several trends are evident. First, the percentage of inspections that resulted in violations has declined significantly from the early unconventional well development years (2008 - 2011). After the adoption of Pennsylvania Act 13 of 2012, the percentage of inspections resulting in violations declined significantly and has stabilized at around 2 percent. In 2018, the number of inspections that result in at least one violation was 2.26 percent of the 18,838 total inspections. Second, over the study period, the average number of environmental health and safety violation per inspection (with violations) increased. In 2018, for every inspection with a violation there was an average of 2.36 violations noted - the highest in the study period.

Generally, these data show that environmental health and safety violations during HVHF-related activities are expected to continue. Despite rules, regulations and industry "best practices," the number of reported violations show an increasing trend from 2014 to 2018. One may infer that an increase in inspection activity is driving an increase in violations; in other words, "the more you look, the more you find". Likewise, "we don't know what we don't know," meaning reported violations are mostly driven by inspections and not all activities are inspected at all times. Activities that could result in violations if discovered by PADP may be well under reported. PADEP inspection data support the conclusion that unreported violations may be occurring despite industry standard practices and best practices and despite Pennsylvania regulations that are in place establishing basic environmental health and safety standards.

The MSC calculation of a 97 percent compliance rate for 2017 conforms with PADEP violations data. In 2017 PADEP reported 16,321 inspections, 827 violations and 382 inspections with violations. The Commission disagrees that a 3 percent failure rate (based on only inspections and reported violations) for compliance with environmental, health and safety rules demonstrate that the industry has a proven track record of operating in a manner that protects our shared environment. A 3 percent failure rate can cause considerable damage to water resources. In addition, violations data and comments from industry representatives commending this failure rate suggest industry has not set a vision or towards significant violations reduction, or an aspirational goal of zero environmental violations that all industries should strive to achieve.

Statement of Concern (SC-108)

The Commission does not have the authority, staff, or funding to oversee and enforce compliance of proposed regulations. The Commission must refrain from finalizing any proposed regulatory program and from processing and issuing permits unless and until questions about resources to enforce adopted regulations have been fully considered and addressed.

Response (R-108)

The Final Regulations prohibit high volume hydraulic fracturing; accordingly, the need for compliance and enforcement measures for this rule, should be minimal.

Statement of Concern (SC-109)

The proposed DRBC regulations should include the ability to assess monetary penalties for non-compliance. In addition, violations should also require offender to rectify damage to streams and rivers and clean up pollution and return damaged resources to pre-existing conditions.

RESPONSE (R-109)

Section 14.17 of the Compact and Article 7 of the Commission's Rules of Practice and Procedure (18 C.F.R. Part 401, Subpart G) provide the Commission with the ability to assess penalties for non-compliance. While the Final Regulations prohibit HVHF activity within the Basin, the Commission will work within its authority and in coordination with the host state to address any resources damages in the unlikely event of a violation of the prohibition.

STATEMENT OF CONCERN (SC-110)

The rules have no mechanisms for monitoring, inspections, and enforcement to ensure that the export of source water or import of wastewater does not degrade water quality in the Basin. Also, there should be provisions requiring and governing the posting of bonds and carriage of appropriate insurance by relevant parties to insure against damages or catastrophe failure. Such provisions are essential if the DRBC is to safeguard the watershed from potential impacts of this activity.

RESPONSE (R-110)

The Commission is withdrawing proposed new Section 440.4 - Exportation of water for hydraulic fracturing of oil and natural gas wells and proposed new Section 440.5 - Produced Water (and importation of wastewater). Public comments specific to sections 440.4 and 440.5 will not be addressed in this comment response document. The topics of water exportation and wastewater importation will be addressed through one or more separate Commission actions.

STATEMENT OF CONCERN (SC-111)

A commenter stated that Pennsylvania is a cautionary tale for this watershed because, between 2008-2016, fracking companies in Pennsylvania together committed more than 5,351 violations, or more than a one violation per day. They suggested that the industry is running rampant over environmental laws, because just 17 percent of the violations result in a fine. They also allege that Pennsylvania DEP clearly is not doing its job, which is why we need the DRBC to act.

RESPONSE (R-111)

According to a search of the Pennsylvania Office of Oil and Gas Management Compliance Report, between 2008 and 2016 there were 5,945 violations reported for unconventional well drilling. Of the 5,954 violations, there were 1,854 enforcement actions (31 percent). That same data set there were 3,131 violations classified as Environmental, Health or Safety. Pennsylvania has an active and comprehensive compliance and enforcement program in those portions of the Commonwealth where hydraulic fracturing activity has historically occurred. The reasons for initiating this rulemaking were outlined in the Notice of Proposed Rulemaking. The Pennsylvania compliance program was not one of the reasons.

2.7 Other Comments Not Specifically Related to the Rules

2.7.1 Air Emissions

Statement of Concern (SC-112)

Commenters highlighted both the positive and negative aspects of air quality impacts associated with hydraulic fracturing activities.

Negative Impacts

- Hydraulic fracturing for natural gas drives the formation of ozone, methane, and other federally regulated air pollutants to levels that violate federal and state air quality standards.

- Degraded air quality from hydraulic fracturing activities potentially threaten public health. Ozone harms human health in many ways, the elderly, infants and children, and can lead to serious illness and death.

- Fracking-related air quality impacts would mean fewer clear views and cloudy skies as in other parts of the country where fracking is prevalent.

- Odors related to the storage, management, and treatment of fracturing fluids and in flowback produced by fracking are also an air quality problem. Odors (e.g. hydrogen sulfide) are not just a nuisance – they can be nauseating, highly toxic and pose a serious human health issue that can greatly affect the quality of life near a well site. Odors can cause illness and even death.

Positive Impacts

- The increased production and use of natural gas benefits the environment due to the increased utilization of natural gas in lieu of much dirtier forms of fossil fuels such as coal and oil.

- Pennsylvania has helped lead the U.S. in the reduction of climate change emissions, thanks to increased use of natural gas in the power generation and transportation sectors.

- Air quality has improved substantially, and by historic proportions, due to the expansion of natural gas use.

- The U.S. leads all industrialized nations in carbon reduction because of abundant natural gas made available by hydraulic fracturing.

Response (R-112)

The Delaware River Basin Compact authorizes the DRBC to provide for the planning, development, conservation, utilization, management and control of the water resources of the Delaware River

Basin. (Compact, § 13.1). The Commission does not control or regulate air emissions or air pollution independent of their effect on water resources. The EPA and the states regulate air quality and air emissions under the federal Clean Air Act and respective state air quality acts and implementing regulations. Although the Commission does not directly regulate air emissions, the Commission has considered air deposition in its development of total maximum daily loads (TMDLs) pursuant to Article 4 of its Water Code and Water Quality Regulations, and in the development of strategies for implementing these TMDLs as appropriate. The final regulations prohibit high volume hydraulic fracturing in the Delaware River Basin and thus preclude air emissions originating within the Basin from this activity.

2.7.2 Natural Gas Pipelines

Statement of Concern (SC-113)

Comments concerning natural gas pipelines are paraphrased as follows:

- Allowing water exports and wastewater imports to support hydraulic fracturing outside the Delaware River Basin will result in the construction of more pipelines and other conveyance structures – more pipelines, and compressor stations, and gas export facilities inflict more harm on our natural resources and communities, both within the watershed and beyond. Too many have already suffered from the impacts of this type of infrastructure.

- The DRBC must not approve any more natural gas pipelines within the DRB or across the river itself. Due to the cumulative adverse effects on the Delaware River, commenters oppose fracking due to the transmission pipelines and related infrastructure (compressors/ export facilities) associated with the development and transport of natural gas.

- In the final report of the Pipeline Infrastructure Task Force, PADEP said, "In the next decade, Pennsylvania will undergo a substantial pipeline infrastructure build-out to transport gas and related by-products from thousands of wells throughout the state . . . . The result will impact communities and the environment in every PA County."

- With pressurized natural gas pipelines come the inherent risk of leaks and deadly explosions, risks that are borne disproportionally by the public/communities through which these facilities cut large swaths of permanently disturbed land.

- DRBC should clarify its authority regarding the regulation of pipeline construction/routing; for instance, are pipelines governed by the draft regulations, and, if so, how does the Commission justify this new authority it seeks to give itself.

Response (R-113)

The regulation of pipelines to transport natural gas or other substances is not within the scope of the proposed or final regulations.

2.7.3 Earthquakes

Statement of Concern (SC-114)

The following are representative of multiple comments expressing concern over the potential for induced earthquakes caused by high volume hydraulic fracking (HVHF) or by the underground injection of HVHF wastewater.

- We urge the Commission to consider the uncontrolled character of fracking's underground explosions and resulting induced seismicity (i.e. earthquakes) caused by both fracking itself and by underground injection of wastewater.

- Petroleum products survive trapped in shale because they are non-polar and do not react with polar rock surfaces. The fracking process replaces the existing unreactive, trapped non-polar fluids with highly polar salt water, almost guaranteeing future seismic activity. It should not be considered in populated areas.

- There are a multitude of documented incidences throughout the nation of increased seismic/earthquake activity associated with hydraulic fracturing, particularly noting a significant increase in areas where such activity was not previously experienced.

Response (R-114)

According to William Ellsworth of the United States Geological Survey's Earthquake Science Center, it is well established that a range of activities, including impoundment of water in reservoirs, surface and underground mining, withdrawal of fluids from the subsurface, and injection of fluids into underground formations, are capable of inducing earthquakes. Typically, seismic events associated with hydraulic fracturing are relatively small in magnitude (less than 2.0) and can be characterized as "microearthquakes" (Ellsworth, 2013). Ellsworth relates "Several cases have recently been reported in which earthquakes large enough to be felt but too small to cause structural damage were associated directly with fracking." Although thousands of wells have been hydraulically fractured over the past fifteen (15) years, few notable seismic events have been registered. According to the Pennsylvania State Seismic Network[78] (PASEIS), the Commonwealth experienced just one hydraulic fracturing-induced event (in April 2016) along the Ohio border [in Lawrence County]. Hydraulic fracturing activity there caused five tremors of magnitudes measuring between 1.8 and 2.3 (levels that are potentially perceptible to the public but incapable of causing structural damage) (Tutela, 2019).[79] However, the actual hydraulic fracturing process does not appear to be responsible for the larger and more significant seismic events that have been detected elsewhere in the nation (see next

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[78] The network is a collaborative monitoring effort between Penn State University, the Bureau of Geological Survey in the Pennsylvania Department of Conservation and Natural Resources (DCNR), and the Pennsylvania Department of Environmental Protection (PA DEP).

[79] According to the author, "Only seismometers deployed onsite by the well operator and those close by in the PASEIS network detected the event."

paragraph). Additional details about the potential for induced seismicity and the creation of migration pathways are presented in Section 2.3.2.4 (Pollution from Fluid Migration).

There is growing evidence that the principal cause of seismic hazards of injection-induced earthquakes is from wastewater disposal in deep underground strata or basement formations Ellsworth, 2013). Such disposal wells are regulated by the U.S. Environmental Protection Agency through its Underground Injection Control (UIC) program pursuant to the Safe Drinking Water Act (40 C.F.R. Parts 144-148). The issue of underground injection of hydraulic fracturing-generated wastewater is addressed generally in Section 2.7.6 below. No oil and gas wastewater disposal wells currently exist within the Delaware River Basin. Because the Commission's final rule prohibits high volume hydraulic fracturing within the Basin (for reasons unrelated to its induced seismicity), the risk of induced seismic activity associated with either HVHF wells or injection disposal wells within the Basin in the foreseeable future is greatly reduced. The importation of HVHF wastewater into the Basin will be the subject of a separate Commission action.

2.7.4 Non-Aquatic Wildlife

Statement of Concern (SC-115)

Commenters express concern about impacts to terrestrial wildlife species and habitats associated with natural gas hydraulic fracturing activity.

Response (R-115)

The Commission acknowledges the risk of adverse effects to wildlife as a result of exposure to hydraulic fracturing wastewater and fracturing fluids. However, impacts on non-aquatic wildlife do not fall directly within the Commission's water resource management charge. Because the Commission's final rule prohibits high volume hydraulic fracturing within the Basin (for reasons unrelated to the impacts of HVHF on non-aquatic wildlife), adverse impacts from HVHF on non-aquatic wildlife within the Basin are not anticipated.

2.7.5 Natural Gas Storage

Statement of Concern (SC-116)

Several commenters urged the Commission to extend the scope of the proposed rules beyond the ban on high volume hydraulic fracturing to prohibit all activities associated with hydraulic fracturing in the Delaware River Basin, including in particular, the storage of natural gas, natural gas liquids and other related materials.

Response (R-116)

The proposed amendments to 18 C.F.R. Part 440 are focused on high volume hydraulic fracturing (HVHF) and related activities. Comments on the storage, transport, treatment and disposal of wastewater from HVHF are addressed in Section 2.3.3.4 (Pollution from Wastewater Handling and Disposal) hereof. The storage of natural gas, natural gas liquids and other natural gas products is otherwise beyond the scope of the proposed rules.

2.7.6 Underground Injection Wells for Disposal of HVHF Wastewater

Statement of Concern (SC-117)

Commenters expressed concern about the use of underground injection wells for disposal of wastewater generated by high volume hydraulic fracturing operations. Representative examples of such comments follow:

- DRBC's proposed regulations should specifically ban injection wells for the storage of contaminated fracking fluids, flowback and produced water, and other types of wastewater. Major risks include permanent loss of water, the substantial risk and inability to remediate ground and surface water contamination, and increased lubricity of faults leading to earthquakes.

- Injection of wastewater does not "treat" waste or remove contaminants; it simply moves the toxic wastewater produced by fracking from one place and time to another. It risks the migration of untreated toxic and radioactive frack wastewater to aquifers and surface water through leaks from the injection well and spills and accidental releases during handling.

- Injection wells are not leak-proof and can expose groundwater and aquifers to contamination from the toxic mix that constitutes untreated frack wastewater when seals are broken, and fractures occur as a result of seismic activity.

Response (R-117)

No underground injection wells currently operate within the Delaware River Basin. Likewise, the Commission's proposed regulations at 18 C.F.R. Part 440 do not address the disposal of wastewater from HVHF within the Basin by means of injection disposal wells. Exercising its discretion to utilize and employ the existing offices and agencies of government "for the purpose of this compact to the fullest extent it finds feasible and advantageous," (Compact § 1.5), the Commission has historically relied upon the EPA and the states to administer a regulatory program for underground injection disposal wells.

Pursuant to the Safe Drinking Water Act of 1974, the U.S. Environmental Protection Agency (EPA) established minimum federal requirements for underground injection control (UIC) programs and other safeguards to prevent waste injection wells from contaminating sources of drinking water (42 U.S.C. § 300f-j; *also see,* U.S. EPA, 2016c). Within the Delaware River Basin, EPA administers the UIC program in Pennsylvania and New York. The New Jersey Department of Environmental Protection and the Delaware Department of Natural Resources and Environmental Control administer UIC regulatory programs in New Jersey and Delaware, respectively.

By prohibiting high volume hydraulic fracturing in the Delaware River Basin, the DRBC's 18 C.F.R. Part 440 regulations substantially reduce the risks to water resources of the Basin associated with the disposal of hydraulic fracturing wastewaters. Furthermore, existing DRBC policy discourages all transfers of wastewater into the Delaware River Basin. The Commission is withdrawing proposed new Section 440.5 - *Produced Water* (and importation of wastewater). The topic of wastewater importation will be addressed through one or more separate Commission actions.

Statement of Concern (SC-118)

The proposed rules discourage potentially non-consumptive water treatment options in favor of consumptive options like UIC disposal, which is not a treatment technology. While today's economics may favor UIC as a disposal option in many parts of the country, this may not always be the case. Treatment technologies for produced water have seen significant technological advances and associated cost reductions over the last five years. Advanced water treatment increasingly is cost competitive when there is limited local UIC capacity or local reuse options.

Response (R-118)

The Commission is withdrawing proposed Section 440.4 - *Exportation of water for hydraulic fracturing of oil and natural gas wells* and proposed Section 440.5 - *Produced Water* (in part addressing imported wastewater). The final rules have been revised to eliminate both sections and any references to them in other proposed new or amended sections. Accordingly, although the Commission disagrees that the proposed rules promoted or discouraged any particular approach to wastewater disposal, the final rules do not address methods of disposal of hydraulic fracturing wastewaters at all.

Notably, by prohibiting high volume hydraulic fracturing in the Delaware River Basin, the DRBC's 18 C.F.R. Part 440 regulations substantially reduce the risks to water resources of the Basin associated with the disposal of hydraulic fracturing wastewaters. Existing DRBC policy discourages all transfers of wastewater into the Delaware River Basin.

2.7.7 Application of Hydraulic Fracturing Produced Water/Wastewater

Statement of Concern (SC-119)

Several commenters expressed concern about the application of hydraulic fracturing-derived wastewater (e.g. brine/salts) for roadway deicing and dust suppression.

Paraphrased comments include:

- Hydraulic fracturing wastewater (treated or untreated), recovered flowback, produced water, and residual solids should not be allowed to be applied to any road or surface within the Delaware River Basin.

- The spreading of oil and gas brine fracking wastes or brines on roads can run off into waterways and contaminate surface waterways and groundwater.

Response (R-119)

The Commission acknowledges the potential risks associated with the application of inadequately treated hydraulic fracturing-derived wastewaters (i.e. produced water/brines). The spreading of oil and gas wastewaters on roadways for deicing or dust suppression is a means by which HVHF activity could impact water resources. Although road spreading has been used as a disposal option for high-TDS wastewaters (brines) from conventional oil and gas production, according to the U.S. EPA, as of 2016, no nationwide estimate of the extent of road spreading using hydraulic fracturing wastewater existed (U.S. EPA, 2016a, p. 8-46). From July 2009 to June 2010, about 13,000 gallons of Marcellus Shale hydraulic fracturing wastewater was reportedly spread on roads in Pennsylvania (Rozell and Reaven, 2011). A 2018 study led by Penn State University found that oil and gas wastewaters spread on roads in the northeastern U.S. have salt, radioactivity, and organic contaminant concentrations often many times above drinking water standards (Tasker *et al.,* 2018). The study also found that in Pennsylvania from 2008 to 2014, spreading oil and gas wastewater on roads released over 4 times more radium to the environment (320 millicuries) than oil and gas wastewater treatment discharges and 200 times more radium than spill events. Lab experiments demonstrated that nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water. These activities and impacts reflect past practices and past regulatory constraints. Currently, road spreading of brine from unconventional wells is explicitly forbidden by Pennsylvania's regulations. *See*, 25 Pa. Code §§ 78a.70 and 78a.70a.

By prohibiting high volume hydraulic fracturing in the Delaware River Basin, the DRBC's proposed 18 C.F.R. Part 440 regulations substantially reduce the risks to water resources of the Basin associated with the disposal of hydraulic fracturing wastewaters. Additionally, existing DRBC policy discourages all transfers of wastewater into the Delaware River Basin.

The Commission is withdrawing proposed new § 440.4 - *Exportation of water for hydraulic fracturing of oil and natural gas wells* and proposed new § 440.5 - *Produced Water* (and importation of wastewater). The final rules have been revised to eliminate both sections and any references to them in other proposed new or amended sections. The topics of water exportation and wastewater importation will be addressed through one or more separate Commission actions. The importation of hydraulic fracturing related brines for roadway deicing and dust suppression will also be considered in these rules.

2.7.8 Miscellaneous

Statement of Concern (SC-120)

A commenter stated that the initial fear of the unknown associated with natural gas drilling in the Susquehanna River Basin "quickly subsided" once residents understood the reality of the situation.

Other commenters, who identified themselves as residents of the Susquehanna River Basin, stated that high volume hydraulic fracturing in Tioga and Susquehanna Counties has resulted in contaminated aquifers and drinking water wells and in the issuance of more than a thousand PADEP notices of violation to the industry in Susquehanna County alone.

Response (R-120)

The DRBC acknowledges submission of these opinions and experiences. The conditions in the Susquehanna River Basin are addressed elsewhere in these responses to comments.

Statement of Concern (SC-121)

Referring to counties that straddle the divide between the Delaware and Susquehanna river basins, a commenter asked whether high volume hydraulic fracturing will be permitted in the portions of those counties located outside the DRB, whether DRBC surveyed those areas to determine whether active Marcellus Shale development is taking place there, and whether the regulations will specify the townships or fragments thereof in which fracking is prohibited.

Response (R-121)

The Compact provides, "The Commission shall have, exercise and discharge its functions, powers and duties within the limits of the Basin, except that it may in its discretion act outside the Basin whenever such action may be necessary or convenient to effectuate its powers or duties within the Basin . . . ." (Compact § 2.7). The DRBC's proposed rules would apply only within the Delaware River Basin. The final rules do not specify individual township/municipalities or portions thereof in which HVHF is prohibited; however, municipalities within the Basin can be readily identified on an interactive map available at: http://drbc.maps.arcgis.com/apps/OnePane/basicviewer/index.html?appid=d87c64691108457fb333df5315dfef03.

Statement of Concern (SC-122)

Multiple commenters expressed concerns about the illegal dumping of fracking waste.

Response (R-122)

The disposal of hydraulic fracturing wastes without required approvals violates federal and state statutes and regulations governing the treatment and disposal of solid wastes and/or discharges of pollutants into water of the United States and/or waters of a Basin state. Because the Commission's final rule prohibits high volume hydraulic fracturing (HVHF) within the Basin, the risk of illegal dumping likely will not increase.

Statement of Concern (SC-123)

Some commenters raised concerns about quality of life impacts associated with high volume hydraulic fracturing activities that are unrelated to water resources. The following exemplify such comments:

- Hydraulic fracturing operations create traffic and transportation-related issues, including congestion and undue wear-and-tear on local roadways that were not designed for the heavy traffic and industrial-sized trucks associated with fracking activities.

- Truck traffic, noise, dirt, pollution and general deterioration and disruption of roadways and daily life associated with the fracking operations also cause stress for local residents. The activities occur 24/7, and the stress continues after the fracking ceases, when the industry's operators are no longer available to address them.

Response (R-123)

The Commission's charge with respect to managing the water resources of the Basin is broad; however, the Commission does not directly regulate traffic and transportation. Spills of hydraulic fracturing fluids or produced waters during transportation and deliberate application of produced water onto roadways are discussed elsewhere in this response to comments. Because the Commission's final rule prohibits high volume hydraulic fracturing (HVHF) within the Basin, Basin residents likely will not experience the traffic, noise, dirt and pollution associated with HVHF.

Statement of Concern (SC-124)

A commenter stated that the majority of fracked natural gas is not consumed domestically but instead is exported to China, France, and Russia.

Response (R-124)

Although this concern is not within the scope of the Commission's authority or its proposed or final rules, according to the United States Energy Information Administration, in 2018, 90 percent of the natural gas produced in the U.S. was consumed domestically (EIA, 2019a). As of 2018, the United States consumed 29.96 trillion cubic feet (Tcf) of natural gas while, at the same time, exported roughly 3.6 Tcf. Exports of natural gas from the U.S. exceeded imports for the first time in 2017. Of the total amount of natural gas exported, more than 75 percent went to Mexico and Canada, while exports to France and China, combined, accounted for only 3 percent and none went to Russia (EIA, 2019d).

Statement of Concern (SC-125)

Several comments concerned the abandoned Barnes Landfill in Barryville, NY. Commenters suggested that DRBC does not care about water quality or pollution because the landfill's leachate holding tank has been overflowing from time to time.

Response (R-125)

In accordance with DRBC's Rules of Practice and Procedure, solid waste landfill projects are subject to state jurisdiction. By letter dated July 18, 2018 to the New York State Department of Environmental Conservation (NYSDEC), DRBC requested that as the primary oversight agency for the landfill, NYSDEC "undertake additional measures to ensure that the landfill is not impacting the Delaware River." The disposition of this issue is unrelated to the proposed rules on high volume hydraulic fracturing.

Statement of Concern (SC-126)

The following are representative of multiple comments expressing concern about the disposal of solid waste from fracking.

- Solid waste disposal is also a concern for water quality, as there is the potential for toxic, radioactive contaminants such as Radium-226 to enter the water cycle via landfill leachate.
- Despite the ban in New York State, fracking waste from Pennsylvania has been accepted at New York landfills with lax oversight for years.
- Under the proposed regulations rock cuttings and sludges from HVHF wells can be transported to the Delaware River Basin and released into waterways. The proposed DRBC regulations do not prohibit disposal of rock cuttings into landfills within the Basin.

Response (R-126)

Federal and state laws and regulations govern the management and disposal of drill cuttings and other solid wastes. The DRBC will continue to review discharges of treated leachate when such discharges meet the thresholds set forth in DRBC's Rules of Practice and Procedure ("RPP"). *See* 18 C.F.R. §§ 401.35(a)(5) and 401.35(b)(8). The DRBC also will continue to review any importation of wastewater (including leachate) into the Basin in accordance with Section 2.30 of the Water Code and the review thresholds established by the RPP. *See,* 18 C.F.R. §§ 401.35(a)(18) and (b)(4).

Statement of Concern (SC-127)

A commenter asked whether unconventional natural gas wells drilled in the Marcellus and Utica formations are hydraulically fractured more than once.

Response (R-127)

EPA reported in 2016 that:

> The portion of the well to be fractured can sometimes be done all at once or done in multiple intervals. When done in multiple intervals, shorter lengths or segments of the well are closed-off (using equipment inserted down into the well) and fractured independently in "stages". Fluids are first injected to clean the well (removing any cement or debris). Then, for each stage fractured, a series of hydraulic fracturing fluid mixtures is injected to initiate fractures and carry the proppant into the fractures. The fracturing process can require moving millions of gallons of fluids around the well site through various hoses and lines, blending and mixing the fluids with proppant, and injecting the mixture at high pressures down the well.

(U.S. EPA, 2016a, p. 3-20; internal citations omitted). Whether or not fractured in stages, most HVHF wells can be fractured more than once over a period of years.

Statement of Concern (SC-128)

A commenter expressed the following concern about potential withdrawals of water to support high volume hydraulic fracturing:

> The proposed application fees are capped at a withdrawal of 75 million gallons per month. There seems to be no financial disincentive for the amount of water to be withdrawn so there is incentive for an applicant to propose the maximum fee and withdraw far greater quantities of water.

Response (R-128)

No change to the Commission's maximum docket application filing fee for a water allocation was proposed in this rulemaking. However, to clarify the record, as of July 1, 2019, the filing fee for a proposed water allocation is $418 per million gallons per month ("MGM") of allocation, with a maximum fee of $15,687. The maximum fee corresponds to a withdrawal of 37.5 MGM (not 75 MGM). *See* 18 C.F.R. § 401.43, Table 1. A higher "alternative review fee" can also be assessed under certain circumstances. *See id.* and 18 C.F.R. § 401.43(b)(3). DRBC's docket decisions contain strict limits on surface and groundwater withdrawals. An applicant cannot withdraw water in excess of an approved limit without being subject to potential penalties for violating the conditions of its docket.

Statement of Concern (SC-129)

One commenter asked why the Commission does not address the antiquated system used by New York City to divert water from the City's Upper Delaware reservoirs to serve users in New York, alleging that the City consumes 50 percent or more of the water in the Delaware River Watershed.

Response (R-129)

Diversions from the Basin by the City of New York are made pursuant to the terms of a Supreme Court decree issued in *New Jersey v. New York*, 347 U.S. 995 (1954), (the "Decree"), seven years before enactment of the Delaware River Basin Compact created the Commission in 1961. The Compact authorizes the Commission to modify the terms of the Decree only with the unanimous consent of the Decree parties, which consist of the four Basin states and New York City (Compact, § 3.3). The City's diversions are not a subject of the proposed regulations.

By way of further background, the Decree allows New York City to divert up to 800 million gallons per day (mgd) on average from the Delaware River Basin. New York City's average daily diversion during calendar year 2016 was approximately 525 mgd. During the same year, total water withdrawals from the Basin averaged 6,565 mgd. Based on these data, New York City's diversion constitutes about 8 percent of the total water withdrawn in the Basin.

New York City has undertaken a $1.0 billion project to repair the leak in its Delaware Aqueduct. The project includes a 2.5-mile bypass tunnel around the most severely leaking sections. The project is expected to be operational in 2023.

STATEMENT OF CONCERN (SC-130)

One commenter stated that the DRBC has a conflict of interest because it accepts funding from the Willman Penn Foundation, which also awards grants the Delaware Riverkeeper Network, an organization opposed to hydraulic fracturing.

RESPONSE (R-130)

The alleged conflict of interest does not exist. Among the powers conferred on the Commission by its organic statute, the Delaware River Basin Compact, the Commission may "[n]egotiate for such loans, grants, services or other aids as may be lawfully available from public or private sources to finance or assist in effectuating any purposes of this compact." Compact, § 3.6(g). *See also*, Compact § 14.1(a)2. The Commission has thus applied for and received funding from many grantors, including the William Penn Foundation, when those grants have advanced the Commission's water resource program objectives. No award of funds by the William Penn Foundation has been conditioned upon any Commission action other than fulfilling the work plan for which the award was made.

The William Penn Foundation committed to making grants totaling $100 million for its "Delaware River Watershed Initiative" ("Initiative"). *See, e.g.,* Kummer, 2018. In Fiscal Year 2020, the Commission received three direct and indirect grants through the Initiative, as itemized in the DRBC budget approved unanimously by the Commission's five members—four governors and a representative of the United States:

- #323 – Academy of Natural Sciences Competitive Grant for Delaware Estuary Modeling
- #324N – Academy of Natural Sciences Competitive Grant for Wastewater Treatment Evaluations for the Delaware River Estuary
- #376 – Outreach Grant for Our Shared Waters Program (direct grant from WPF).

The total value of the three grants is $1.28 million over three years, making the DRBC a relatively minor grantee from the Initiative portfolio. As noted in the Commission's FY2021 budget, combined revenues from the three WPF grants equal $199,700 for that fiscal year, about two percent of the Commission's total revenues in FY2021.

The DRBC does not receive funding from the Delaware Riverkeeper Network and has no relationship with DRN other than its public relationship. The relationship between the William Penn Foundation and the Delaware Riverkeeper Network is of no relevance to the Commission's actions.

Grants that help to support DRBC programs are subject to review and approval by the Commissioners and are disclosed to the public through actions outlined in resolutions. Commission finances are reviewed by an independent auditor each year, and the audit results provided to the public. In November 2018 the Pennsylvania Auditor General conducted a performance audit of the DRBC (PA DAG, 2018). The annual independent financial audits and the Auditor General's performance audit found no evidence of conflicts of interest with any individual or entity.

Statement of Concern (SC-131)

According to one commenter, the DRBC should be abolished, it serves no purpose and does not represent the people.

Response (R-131)

The Commission acknowledges but disagrees with this opinion. The DRBC has a long and successful history of managing, protecting and improving the water resources of the Delaware River Basin to the benefit of over 13 million people in four states, consistent with its authority provided by state and federal law.

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APPENDIX-1 RESOLUTION NO. 2021 – 01

NO. 2021-01

A RESOLUTION to amend the Comprehensive Plan and adopt implementing regulations with respect to high volume hydraulic fracturing and to finalize amendments to the *Administrative Manual – Rules of Practice and Procedure* concerning project review classifications and fees.

WHEREAS, at the business meeting of the Delaware River Basin Commission ("DRBC" or "Commission") on May 5, 2010, the DRBC Commissioners unanimously directed DRBC staff "to develop draft regulations on well pads in the shales for notice and comment rulemaking;" and

WHEREAS, the Commission on December 9, 2010 published draft regulations concerning natural gas development on which it subsequently received nearly 69,000 comments, and on November 8, 2011 the Commission published revised draft natural gas development regulations; and

WHEREAS, the Minutes for DRBC's business meetings of March, May and July of 2012 record that the Commissioners and members of their technical staffs continued to consult with one another and work in good faith toward consensus on technical aspects of the Commission's natural gas development regulations; and

WHEREAS, in December 2013, DRBC Alternate Commissioner Angus Eaton of the New York Department of Environmental Conservation ("Department" or "NYSDEC") on behalf of Commission Chair *pro tem* Governor Andrew Cuomo of the State of New York reported that the Commission would rely on the results, when published, of studies that had been initiated by state and federal agencies for guidance in setting minimum standards for natural gas development in the Basin; and

WHEREAS, in June 2015, the NYSDEC issued its *Final Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program* ("FSGEIS"), which concluded that, "[e]ven with the implementation of an extensive suite of mitigation measures considered by the Department . . . , the significant adverse public health and environmental impacts from allowing high-volume hydraulic fracturing to proceed under any scenario cannot be adequately avoided or minimized to the maximum extent practicable in accordance with [the State Environmental Quality Review Act];" and

WHEREAS, in December 2016, the U.S. Environmental Protection Agency ("U.S. EPA") published its report entitled, *Hydraulic Fracturing for Oil and Gas: Impacts From the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States,* which concluded that "the uses of water in hydraulic fracturing, from water withdrawals . . . through mixing and injection . . . to the collection and disposal or reuse of produced water . . . can impact drinking water resources under some circumstances;" and that such impacts "can range in frequency and severity, depending on the combination of hydraulic fracturing water cycle activities and local- or regional-scale factors;" and

WHEREAS, in March of 2017, DRBC Alternate Commissioner LTC Michael A. Bliss of the United States Army Corps of Engineers, Philadelphia District, acting on behalf of Commission Chair *pro tem* Maj. Gen. William H. Graham for the United States, announced that the Commissioners continued to confer in good faith on a path forward for adoption of rules regarding natural gas development and hydraulic fracturing in the Basin; the Commission at that time had no plans to vote on the draft rules published in 2011; and any new or continued rulemaking by the Commission would be subject to further public notice and comment; and

WHEREAS, by Resolution for the Minutes on September 13, 2017, noting that the combination of hydraulic fracturing with horizontal drilling and related activities for natural gas extraction presents risks, vulnerabilities and impacts to surface and ground water resources in the Delaware River Basin ("Basin"), the Commission directed the Executive Director to publish no later than November 30 of that year a set of revised draft regulations regarding certain natural gas development activities in the Basin; and

WHEREAS, on November 30, 2017 the Commission issued a Notice of Proposed Rulemaking, FAQs, proposed rule text, and technical guidance to:

- amend its Special Regulations by the addition of a part on hydraulic fracturing, including: the prohibition of high volume hydraulic fracturing ("HVHF") in shale and other tight formations within the Basin, and conditions relating to water use for hydraulic fracturing and the management of hydraulic fracturing wastewater;

- amend its *Administrative Manual – Rules of Practice and Procedure* ("RPP") by the addition of project review classifications and fees related to the management of water for and produced water from hydraulic fracturing of hydrocarbon bearing rock formations; and

- amend the RPP by revising certain project review classifications unrelated to hydraulic fracturing; and

WHEREAS, prior to the close of the comment period on March 30, 2018, six public hearings on the draft rules were held – two in Waymart, Pennsylvania in January 2018; two in Philadelphia, Pennsylvania the same month; one in February 2018 in Schnecksville, Pennsylvania, and another, telephonically, on March 6, 2018; and

WHEREAS, during the comment period, the Commission heard oral comment on the draft rules from approximately 223 individuals and received 8,679 written submissions, many of which included multiple comments. Transcripts from each of the public hearings and copies of all the written comments were posted on the DRBC website on April 10, 2018; and

WHEREAS, in the course of carefully reviewing the comments submitted on the draft rules, the Commission also has considered the large body of scientific research published since NYSDEC issued its FSGEIS in June 2015 and the U.S. EPA released its final report on the impacts of the hydraulic fracturing water cycle on drinking water in December 2016, largely confirming and expanding upon the findings of those reports and supporting the conclusion that HVHF poses immediate and long-term risks to water resources, human health and aquatic life in the Delaware River Basin; and

WHEREAS, in developing the revised rules, the Commission has considered its Comprehensive Plan, which among other things contains:

a. provisions codified in the Commission's Water Code, 18 C.F.R. Part 410, protecting the uses of groundwater for domestic, agricultural, industrial and public water supplies and as a source of surface water suitable for recreation, wildlife, fish and other aquatic life (Water Code § 3.40.3 A.), and authorizing the Commission to establish requirements, conditions, or prohibitions which in its judgment are necessary to protect ground water quality (Water Code § 3.40.5 B.3.). *See also,* Water Code provisions:

§ 2.20.5, protecting recharge areas and prohibiting pollution of underground waters and surface waters replenishing underground waters;

§ 3.40.4 A., protecting groundwater from the introduction of substances in concentrations that are toxic or harmful to human, animal, plant or aquatic life or that exceed federal drinking water standards;

§ 3.40.4 B., prohibiting degradation of groundwater quality including any degradation that may be injurious to any designated present or future ground or surface water use;

§ 3.40.5 B.1., prohibiting any person from permitting substances in harmful or toxic concentrations to become groundwater; and

§ 3.40.5 A., requiring persons to conduct their activities in compliance with Commission regulations so as to prevent requirements of Water Code § 3.40 (relating to groundwater) from being violated; and

b. provisions codified in the Water Code protecting the quality of the Basin's surface waters, including for example:

§ 3.10.2 B., providing that uses to be protected in all surface waters of the Basin include, among others, public water supplies (except where natural salinity precludes such use) and aquatic life;

§§ 3.20.2 through 3.20.6, protecting interstate, non-tidal surface waters for, among other uses, public water supply and maintenance and propagation of aquatic life; and

§ 3.10.3 A.2., protecting waters classified by the Commission as Special Protection Waters by establishing for such waters a management objective of "no measurable change . . . except toward natural conditions."; and

WHEREAS, the Commission staff, in consultation with the Commissioners and their technical and policy advisors, has developed a detailed response to comments and set of revised rules responsive to the comments received; now therefore,

BE IT RESOLVED by the Delaware River Basin Commission:

A. The Commission hereby finds and determines that:

1. As the scientific and technical literature and the reports, studies, findings and conclusions of other government agencies reviewed by the Commission have documented, and as the

more than a decade of experience with high volume hydraulic fracturing in regions outside the Delaware River Basin have evidenced, despite the dissemination of industry best practices and government regulation, high volume hydraulic fracturing and related activities have adversely impacted surface water and groundwater resources, including sources of drinking water, and have harmed aquatic life in some regions where these activities have been performed.

2. The region of the Delaware River Basin underlain by shale formations is comprised largely of rural areas dependent upon groundwater resources; sensitive headwater areas considered to have high water resource values; and areas draining to DRBC Special Protection Waters.

3. The geology of the region in which shale formations potentially containing natural gas are located in the Basin is characterized by extensive geologic faults and fractures providing preferential pathways for migration of fluids (including gases).

4. If commercially recoverable natural gas is present in the Delaware River Basin and if high volume hydraulic fracturing ("HVHF") were to proceed in the Basin, then:

   a. Spills and releases of hydraulic fracturing chemicals, fluids and wastewater would adversely impact surface water and groundwater, and losses of well integrity would result in subsurface fluid (including gas) migration, impairing drinking water resources and other uses established in the Comprehensive Plan.

   b. The fluids released or migrating would contain pollutants, including salts, metals, radioactive materials, organic compounds, endocrine-disrupting and toxic chemicals, and chemicals for which toxicity has not been determined, impairing the water uses protected by the Comprehensive Plan.

   c. HVHF activities and their impacts would be dispersed over and adversely affect thousands of acres of sensitive water resource features, including, among others, forested groundwater infiltration areas, other groundwater recharge locations, and drainage areas to Special Protection Waters, where few existing roads are designed to safely carry the heavy industrial traffic required to support HVHF, prevent dangerous spills or provide access to remediate spills that occur.

5. For the foregoing reasons and other grounds described in the administrative record for this rulemaking:

   a. High-volume hydraulic fracturing and related activities pose 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, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values.

   b. Controlling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

B. The Commission hereby withdraws from further consideration the draft natural gas development regulations it published on November 8, 2011; and

1. Adopts the February 25, 2021 Comment and Response Document in its entirety.

2. Adopts the revised rules attached hereto as its final rules and incorporates 18 CFR Part 440 into the Comprehensive Plan. The final rules at 18 CFR Part 440.3 provide that high volume hydraulic fracturing in hydrocarbon-bearing rock formations is prohibited within the Delaware River Basin.

3. Underscores that the final rules include the following noteworthy changes from those proposed on November 30, 2017:

    a. Within final Part 440 - High Volume Hydraulic Fracturing, of Title 18 of the Code of Federal Regulations ("CFR"), proposed sections 440.4 – Exportation of water for hydraulic fracturing and 440.5 – Produced water have been removed in their entirety, and section 440.2 – Definitions has been revised to eliminate terms associated solely with the two deleted sections.

    b. Within Part 401 of Title 18 of the CFR, comprising the Commission's Rules of Practice and Procedure, proposed amendments to section 401.35 – Classification of Projects for Review concerning the importation and exportation of water and wastewater into and from the Basin have been withdrawn.

    c. Also, within Part 401, proposed amendments to section 401.43 – Regulatory Program Fees related to wastewater treatability studies have been withdrawn.

C. The Comprehensive Plan amendments and final rules adopted today replace the Executive Director Determinations of May 19, 2009, June 14, 2010 and July 23, 2010. The Resolution for the Minutes of May 5, 2010, which postponed the Commission's consideration of well pad projects until the adoption of final rules, expires by its own terms.

D. The Commission's regulations concerning the exportation from and importation into the Basin of water and wastewater to support hydraulic fracturing will be addressed through one or more separate Commission actions, including if appropriate a separate rulemaking.

BY THE COMMISSION

ADOPTED: February 25, 2021

The final amendments to existing 18 C.F.R. § 401.35 are as follows:

§ 401.35 Classification of projects for review under Section 3.8 of the Compact.

(a) Except as the ~~Executive Director~~ Commission may specially direct by notice to the project owner or sponsor, ~~or as a state or federal agency may refer under paragraph (c) of this section,~~ a project in any of the following classifications will be deemed not to have a substantial effect on the water resources of the Basin and is not required to be submitted under Section 3.8 of the Compact:

* * * * *

(2) A withdrawal from ground water ~~for any purpose~~ when the daily average gross withdrawal during any 30 consecutive day period does not exceed 100,000 gallons;

* * * * *

(15) Draining, filling or otherwise altering marshes or wetlands when the area affected is less than 25 acres; provided~~;~~, however, that areas less than 25 acres shall be subject to Commission review and action ~~(i)~~ where neither a state nor a federal level review and permit system is in effect; ~~requiring action by the Commission, or (ii) when a Commissioner or the Executive Director determines that the final action of a state or federal permitting agency may not adequately reflect the Commission's policy as to wetlands of the Basin. In the case of a project affecting less than 25 acres for which there has been issued a state or federal permit, a determination to undertake review and action by the Commission shall be made no later than 30 days following notification of the Commission of such permit action. The Executive Director, with the approval of the Chairman, may at any time within the 30-day period inform any permit holder, signatory party or other interested party that the Commission will decline to undertake review and action concerning any such project;~~

* * * * *

(b) All other projects which have or may have a substantial effect on the water resources of the Basin shall be submitted to the Commission in accordance with these regulations for determination as to whether the project impairs or conflicts with the Comprehensive Plan. Among these are projects involving the following (except as provided in paragraph ~~A.~~ (a) of this section):

* * * * *

~~(14) Regional wastewater treatment plans developed pursuant to the Federal Water Pollution Control Act;~~

(14~~5~~) Landfills and solid waste disposal facilities affecting the water resources of the basin;

(15~~6~~) State and local standards of flood plain regulation;

(1~~7~~6) Electric generating or cogenerating facilities designed to consumptively use in excess of 100,000 gallons per day of water during any 30-day period; and

(~~18~~17) Any other project that the ~~Executive Director~~ Commission may ~~e~~specially direct by notice to the project sponsor or land owner as having a potential substantial water quality impact on waters classified as Special Protection Waters.

(c) Regardless of whether expressly excluded from review by paragraph (a) of this section, any project or class of projects that in the view of the Commission could have a substantial effect on the water resources of the basin may, upon special notice to the project sponsor or landowner, be subject to the requirement for review under section 3.8 of the Compact. ~~Whenever a state or federal agency determines that a project falling within an excluded classification (as defined in paragraph (a) of this section) may have a substantial effect on the water resources of the Basin, such project may be referred by the state or federal agency to the Commission for action under these Rules.~~

~~(d) Except as otherwise provided by § 401.39 the sponsor shall submit an application for review and approval of a project included under paragraph B. above through the appropriate agency of a signatory party. Such agency will transmit the application or a summary thereof to the Executive Director, pursuant to Administrative Agreement, together with available supporting materials filed in accordance with the practice of the agency of the signatory party.~~

The final amendments to existing 18 C.F.R. § 401.43 are as follows:

§ 401.43 Regulatory program fees.

* * * * *

(b) * * *

(1) *~~Docket a~~ Application fee.* Except as set forth in paragraph (b)(1)(iii) of this section, the ~~docket~~ application fee shall apply to:

* * * * *

(iii) *Exemptions.* The ~~docket~~ application fee shall not apply to:

* * * * *

(2) *Annual monitoring and coordination fee*.

(i) Except as provided in paragraph (b)(2)(ii) of this section, an annual monitoring and coordination fee shall apply to each active water allocation or wastewater discharge approval issued pursuant to the *Compact* and implementing regulations, regardless of whether the approval was issued by the Commission in the form of a docket, permit or other instrument, or by a Signatory Party Agency under the One Permit Program rule (§ 401.42). ~~The fee shall be based on the amount of a project's approved monthly water allocation and/or approved daily discharge capacity.~~

* * * * *

(4) * * *

(iii) *Modification of a DRBC approval.* Following Commission action on a project, each project revision or modification that the Executive Director deems substantial shall require an additional ~~docket~~ application fee calculated in accordance with paragraph (e) of this section and subject to an alternative review fee in accordance with paragraph (b)(3) of this section.

* * * * *

(c) *Indexed adjustment.* On July 1 of every year, beginning July 1, 2017, all fees established by this section will increase commensurate with any increase in the annual April 12-month Consumer Price Index (CPI) for Philadelphia, published by the U.S. Bureau of Labor Statistics during that year.[1] In any year in which the April 12-month CPI for Philadelphia declines or shows no change, the ~~docket~~ application fee and annual monitoring and coordination fee will remain unchanged. Following any indexed adjustment made under this paragraph (c), a revised fee schedule will be published in the *Federal Register* by July 1 and posted on the Commission's website. Interested parties may also obtain the fee schedule by contacting the Commission directly during business hours.

[1] Consumer Price Index – U / Series ID: CWURA102SA0 / Not Seasonally Adjusted / Area: Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD / Item: All items / Base Period: 1982-84=100.

*   *   *   *   *

(e)   *   *   *

TABLE 1 TO § 401.43 – ~~DOCKET~~ APPLICATION ~~FILING~~ FEES

Project Type	~~Docket~~ Application Fee	Fee Maximum
	* * * * * * *	
	* * * * * * *	
	* * * * * * *	

*   *   *   *   *   *

The final text of new Part 440 is as follows:

SUBCHAPTER B – SPECIAL REGULATIONS

* * * *

PART 440 – HIGH VOLUME HYDRAULIC FRACTURING

440.1 Purpose, authority and relationship to other requirements.

(a) *Purpose.* The purpose of this part is to protect and conserve the water resources of the Delaware River Basin. To effectuate this purpose, this section establishes standards, requirements, conditions and restrictions to prevent or reduce depletion and degradation of surface and groundwater resources and to promote sound practices of water resource management.

(b) *Authority.* This part implements Sections 3.1, 3.2(a), 3.2 (b), 3.6(b), 3.6(h), 4.1, 5.2, 7.1, 13.1 and 14.2(a) of the Delaware River Basin Compact.

(c) *Comprehensive Plan.* The Commission has determined that the provisions of this part are required for the immediate and long range development and use of the water resources of the Basin and are therefore incorporated into the Commission's Comprehensive Plan.

(d) *Relationship to other Commission requirements.* The provisions of this part are in addition to all applicable requirements in other Commission regulations, dockets and permits.

(e) *Severability.* The provisions of this part are severable. If any provision of this part or its application to any person or circumstances is held invalid, the invalidity will not affect other provisions or applications of this part, which can be given effect without the invalid provision or application.

(f) *Coordination and avoidance of duplication.* In accordance with and pursuant to section 1.5 of the Delaware River Basin Compact, to the fullest extent it finds feasible and advantageous the Commission may enter into an Administrative Agreement (Agreement) with any Basin state or the federal government to coordinate functions and eliminate unnecessary duplication of effort. Such Agreements will be designed to: effectuate intergovernmental cooperation, minimize the efforts and duplication of state and Commission staff resources wherever possible, ensure compliance with Commission-approved requirements, enhance early notification of the general public and other interested parties regarding proposed activities in the Basin, indicate where a host state's requirements satisfy the Commission's regulatory objectives and clarify the relationship and project review decision making processes of the states and the Commission for projects subject to review by the states under their state authorities and by the Commission under Section 3.8 and Articles 6, 7, 10 and 11 of the Compact.

440.2 Definitions.

For purposes of this part, the following terms and phrases have the meanings provided. Some definitions differ from those provided in regulations of one or more agencies of the Commission's member states and the federal government.

Basin - the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

Commission - the Delaware River Basin Commission (DRBC) created and constituted by the Delaware River Basin Compact.

Fracturing fluid(s) - a mixture of water (whether fresh or recycled) and/or other fluids and chemicals or other additives, which are injected into the subsurface and which may include chemicals used to reduce friction, minimize biofouling of fractures, prevent corrosion of metal pipes or remove drilling mud damage within a wellbore area, and propping agents such as silica sand, which are deposited in the induced fractures.

High volume hydraulic fracturing (HVHF) - hydraulic fracturing using a combined total of 300,000 or more gallons of water during all stages in a well completion, whether the well is vertical or directional, including horizontal, and whether the water is fresh or recycled and regardless of the chemicals or other additives mixed with the water.

Hydraulic Fracturing - a technique used to stimulate the production of oil and natural gas from a well by injecting fracturing fluids down the wellbore under pressure to create and maintain induced fractures in the hydrocarbon-bearing rock of the target geologic formation.

Person - any natural person, corporation, partnership, association, company, trust, federal, state or local governmental unit, agency, or authority, or other entity, public or private.

Water resource(s) - water and related natural resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership or control within the hydrologic boundary of the Delaware River Basin.

440.3 High volume hydraulic fracturing (HVHF)

(a) **Determination.** 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, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values. Controlling future pollution by prohibiting such activity in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

(b) **Prohibition.** High volume hydraulic fracturing in hydrocarbon bearing rock formations is prohibited within the Delaware River Basin.

APPENDIX-2 GLOSSARY OF WASTEWATER TERMS

Wastewater Definitions
Source: EPA, 2016b, pp. xiii-xx.

Base fluid **-** The primary component of fracturing fluid to which proppant (sand) and chemicals are added. Hydraulic fracturing base fluids are typically water-based; however, there are cases of non-aqueous fracturing fluids (e.g., compressed nitrogen, propane, carbon dioxide). Water-based fluid may consist of only fresh water or a mixture of fresh water, brackish water and/or reused/recycled wastewater

Drilling wastewater - The liquid waste stream separated from recovered drilling mud (fluid) and drill cuttings during the drilling process.

Flowback **-** The produced water generated in the initial period after hydraulic fracturing prior to production (i.e., fracturing fluid, injection water, any chemicals added downhole, and varying amounts of formation water).

Formation water - Water that occurs naturally within the pores of rock.

Produced sand - The slurried particles used in hydraulic fracturing, the accumulated formation sands and scales particles generated during production. Produced sand also includes desander discharge from the produced water waste stream, and blowdown of the water phase from the produced water treating system.

Produced water (brine) - The fluid (brine) brought up from the hydrocarbon-bearing strata during the extraction of oil and gas, and includes, where present, formation water, injection water, and any chemicals added downhole or during the oil/water separation process.

Proppant - A granular substance (e.g., sand grains, aluminum pellets) that is carried in suspension by the fracturing fluid and that serves to keep the cracks open when fracturing fluid is withdrawn after a fracture treatment.

Hydraulic fracturing wastewater[80] **-** Wastewater sources associated with production, field exploration, drilling, well completion, or well treatment for unconventional oil and gas extraction (including, but not limited to, drilling muds, drill cuttings, produced sand, produced water).

[80] The EPA document uses the term "UOG extraction wastewater," not "hydraulic fracturing wastewater."

APPENDIX-3 DISCUSSION OF API REFERENCED STUDIES

This appendix discusses the findings of 20 studies that were offered in comments by the American Petroleum Institute (API) as "reputable studies by government agencies and academic institutions, [that] coupled with empirical evidence, … lead one to firmly conclude that hydraulic fracturing is not a threat to drinking water resources…." (API, 2018, p. 6). Based on a review of the documentation of these 20 studies, as summarized below, and in consideration of the many other relevant and compelling studies referenced elsewhere in this Comment and Response Document that were absent from the API comments, the Commission disputes this conclusion.

In response to the API statement that these studies are "by government agencies and academic institutions," an examination of author affiliations and sources of funding for these studies indicates that some of them were conducted and/or funded by parties other than government agencies and academic institutions. Author affiliations and funding sources are noted in the summaries below to clarify the involvement of any parties other than government agencies and academic institutions.

Harkness, J.S., Darrah, T.H., Warner, N.R., Whyte, C.J., Myles T. Moore, M.T., Millot, R., Kloppman, W., Jackson, R.B., Vengosh, A., 2017. The Geochemistry of Naturally Occurring Methane and Saline Groundwater in an Area of Unconventional Shale Gas Development. Geochimica et Cosmochimica Acta, 208(1), p. 302-334.

https://www.sciencedirect.com/science/article/pii/S0016703717302004?via%3Dihub

NOTE: THIS STUDY IS LISTED IN THE API COMMENT AS "VENGOSH *ET AL.*, 2017"; THE AUTHORS ARE ACADEMICIANS WITH DUKE UNIVERSITY, THE OHIO STATE UNIVERSITY, PENNSYLVANIA STATE UNIVERSITY, STANFORD UNIVERSITY, AND AN EMPLOYEE OF THE FRENCH GEOLOGICAL SURVEY. THE STUDY WAS FUNDED BY THE NATIONAL SCIENCE FOUNDATION AND THE NATURAL RESOURCES DEFENSE COUNCIL.

The researchers aimed to investigate geochemical variations of groundwater and surface water before, during, and after hydraulic fracturing in the study area and to distinguish natural from human sources of natural gas and salt contaminants.

The study concluded that saline and hydrocarbon-rich groundwater originated from naturally occurring sources, likely from deeper methane-rich brines that had interacted with coalbeds. The saline and hydrocarbon-rich groundwater found in drinking water wells tested in this study were present prior to shale oil and gas development. Although the data showed a lack of changes in water quality after installation of shale gas wells during the 3-year period of the investigation, the researchers recommended that future studies should address the potential for groundwater contamination over longer periods of time.

The study found surface water contamination at three sites that originated directly from surface spills associated with unconventional oil and gas activities. The researchers concluded that:

> . . . the chemistry and isotope ratios of surface waters (*n* = 8) near known spills or leaks occurring at disposal sites mimicked the composition of Marcellus flowback fluids, and show direct evidence for impact on surface water by fluids accidentally released from nearby shale-gas well pads and oil and gas wastewater disposal sites.

The study authors conclude, in part, that their results show direct evidence for impacts to surface water quality as a result of HVHF activity. Therefore, the study does not support the conclusion "that hydraulic fracturing is not a threat to drinking water."

McMahon, P.B., Barlow, J.R.B., Engle, M. A., Belitz, K., Ging, P. B., Hunt, A.G., Jurgens, B.C., Kharaka, Y.K., Tollett, R.W., and Kresse, T.M., 2017. Methane and Benzene in Drinking-Water Wells Overlying the Eagle Ford, Fayetteville, and Haynesville Shale Hydrocarbon Production Areas. Environmental Science & Technology, 51(12), p. 6727-6734. DOI: 10.1021/acs.est.7b00746.

NOTE: THIS STUDY IS LISTED IN THE API COMMENT AS "U.S. GEOLOGICAL SURVEY (USGS), 2017". THE AUTHORS ARE EMPLOYEES OF THE U.S. GEOLOGICAL SURVEY. THE STUDY WAS FUNDED BY THE USGS NATIONAL WATER-QUALITY ASSESSMENT (NAWQA) PROGRAM AND ENERGY RESOURCES PROGRAM.

This research studied the groundwater quality in three major U.S. shale gas & oil plays: The Eagle Ford (Texas), Fayetteville (Arkansas), and Haynesville (Louisiana and Texas). The study: investigates the occurrence and sources of methane and benzene in 116 drinking water wells overlying these 3 formations; provides data on co-occurrences of methane, benzene, and other VOCs in drinking water wells in the EF-FV-HV play areas; and examines possible links between biogenic methane and hydrocarbon degradation.

The data collected indicates that groundwater contained little, if any, water from EF, FV, or HV shales. Moreover, methane concentrations in the groundwater samples were not spatially correlated with hydrocarbon well locations. Methane isotopic and hydrocarbon-gas composition data indicate the shale gas in the study areas was thermogenic and compositionally different from most of the groundwater methane. Two groundwater samples contained methane from the fermentation pathway that could be associated with hydrocarbon degradation based on their co-occurrence with hydrocarbons such as ethylbenzene and butane. The study found that unconventional oil and gas plays were not important sources of methane in the groundwater wells sampled. There was a lack of correlation between groundwater-methane concentrations and hydrocarbon well locations, densities, and drilling years.

This study found that unconventional oil and gas operations did not contribute substantial amounts of methane or benzene to the sampled drinking water wells in the EF, FV, or HV shale play study areas, however, the groundwater age-data collected, and the inferred groundwater travel times suggest that it may take decades to assess fully the effects of potential subsurface and surface releases of hydrocarbons on wells. Although the study did not find clear evidence of groundwater impacts from HVHF activities, the age-tracer results indicate considerable uncertainty about the long-term risks of HVHF activities to groundwater resources. The authors of this report do not conclude that hydraulic fracturing is not a threat to drinking water.

U.S. EPA, 2016. Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States (Final Report) U.S. Environmental Protection Agency, Washington, DC, EPA-600-R-16-236Fa, 666 p.
https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990

NOTE: THE AUTHORS, CONTRIBUTORS, AND REVIEWERS OF THE REPORT ARE EMPLOYEES OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY AND THE CADMUS GROUP, INC. THE STUDY WAS REQUESTED BY CONGRESS AND FUNDED BY THE U.S. GOVERNMENT.

API is offering this 2016 EPA study to support its statement that "hydraulic fracturing is not a threat to drinking water resources". Within the same comment letter, API acknowledges and strongly disagrees with the 2016 conclusions of this study that "*that activities under the hydraulic fracturing water cycle can impact drinking water resources under some circumstances.*" The comments from API and others about the EPA reports are addressed elsewhere in this comment response document. When facts, data, and science show the potential for severe impacts and threats to drinking water quality, API disagrees with the EPA results and conclusions in this report. When EPA results and conclusions suggest that some impacts and threats are unlikely or less frequent, API will generally agree with the EPA. Vulnerabilities and related threats are defined by both the frequency of impacts and the potential severity of impacts; therefore, this study does not support API's statement that "hydraulic fracturing is not a threat to drinking water resources."

Acton Mickelson Environmental and Wyoming Department of Environmental Quality, 2016. Pavillion, Wyoming Area Domestic Water Wells Final Report and Palatability Study. Wyoming Department of Environmental Quality, Cheyenne, Wyoming, 120 p.
http://deq.wyoming.gov/wqd/pavillion-investigation/resources/investigation-final-report/

NOTE: THIS STUDY IS LISTED IN THE API COMMENT AS "WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY, 2016." THE AUTHORS OF THE REPORT ARE ACTON MICKELSON ENVIRONMENTAL, INC., AND WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY. THE SOURCE OF FUNDING IS NOT DISCLOSED IN THE REPORT.

The comment cites the report as "Wyoming Department of Environmental Quality, 2016", and provides a web link to the document. However, the web link provided in the comment is to a draft report which was released on December 14, 2015 (AME and WY DEQ, 2015). The final report for the same study was released on November 7, 2016 (AME and WY DEQ, 2016). It is unclear which version of the report the commenter intended to cite. The Commission notes that the conclusions of both report versions are nearly identical, with only minor differences.

This study provides results of an investigation into water quality issues within the Pavillion Gas Field in the rural area east of Pavillion, Wyoming that relies on well water. The Pavillion Gas Field is an unconventional reservoir, with gas produced from permeable sandstones of the Wind River Formation and the underlying Fort Union Formation. The Wind River Formation also supplies the area's drinking water. This study evaluated 14 water supply wells (domestic, irrigation, and stock) in the Pavillion Gas Field for water quality, taste, and other issues.

The study results suggest that upward gas seepage was occurring naturally in the area before gas well development and that it is unlikely that hydraulic fracturing fluids seeped upward from production zones to groundwater supply wells directly or along offset or abandoned gas wells. It has not been determined if fluids seeping along the gas wells have entered shallow permeable zones. In this event, the researchers state, the quantification of the gas seepage along gas wells versus natural upward migration would be difficult. After reviewing sampling results, the researchers suggest that there is potential for inorganic compounds (chloride, potassium, sulfate) from gas pits to contribute to high levels of salts and other compounds found in water supply wells, however, additional assessments are needed to evaluate groundwater protection measures at the wells. Methane found in water supply wells in this study likely contains methane from naturally occurring sources and possibly (but not known with certainty) from gas seepage from an intermediate depth along the wellbore of gas wells. Existing data were insufficient to determine if a spatial correlation exists between gas pits and pit-derived constituents in groundwater samples from nearby wells. The study found that there is potential communication of groundwater and/or gas between shallow water-bearing zones and the intermediate zone above the gas production layers (where both are intercepted by gas wells. The most likely conditions for vertical seepage to occur include:

- a gas well with an annular space without cement adjacent to production casing;
- a relatively shallow surface casing in the same gas well;
- an intermediate permeable zone pressurized by gas; and
- one or more permeable groundwater zones that intersect the gas well below the surface casing shoe.
- Limited pre-development baseline data for Pavillion Gas Field limits evaluation of the causes and effects of changes in water quality.

As far as attributing water well impacts in the Pavillion Gas Field to any sources, the study is inconclusive, and, therefore, it does not support the conclusion that hydraulic fracturing is not a threat to drinking water resources.

Botner, E.C., Townsend-Small, A., Nash, D.B., Xu, X., Schimmelmann, A., and Miller, J.H., 2018. Monitoring concentration and isotopic composition of methane in groundwater in the Utica Shale hydraulic fracturing region of Ohio. Environmental Monitoring and Assessment, 190:322. doi:10.1007/s10661-018-6696-1 .

NOTE: THE STUDY IS LISTED IN THE API COMMENT AS "TOWNSEND-SMALL *ET AL.,* 2016." THE AUTHORS ARE ACADEMICIANS WITH THE UNIVERSITY OF CINCINNATI, UNIVERSITY OF CALIFORNIA (IRVINE), AND INDIANA UNIVERSITY. THE STUDY WAS FUNDED BY THE DAVID & SARA WESTON FOUNDATION AND THE DEER CREEK FOUNDATION.

Researchers from the University of Cincinnati tested public wells in the Utica Shale region in Carroll County, Ohio. The study found no relationship between methane concentration in groundwater and proximity to active gas well sites (within more than 5 kilometers), despite the large increase in the number of active shale gas wells in the study area. Of the datasets with three or more observations, the majority showed methane concentration decreasing with time. However, the number of samples in the time series is relatively small.

The data indicate high levels of biogenic methane, which can be present in groundwater wells unrelated to hydraulic fracturing activities. Biogenic methane can be derived from an organic matter source, such as soil or plants, or from reduction of CO2 as with coalbed methane.

The samples from the study also showed no significant change in pH or conductivity over time in groundwater samples from proximal wells (within 5 km of the nearest active shale gas well.) The authors noted several caveats that bear on the robustness of their findings:

- There may be natural variability in concentrations of biogenic methane in the groundwater of the study area.
- The researchers note that they may lack statistical power to uncover a robust signal in data that may be characterized by natural variability.
- Samples that fell into the range of methane from natural gas sources may have small amounts of natural gas from nearby conventional wells or newly drilled unconventional oil and gas wells.
- There may be a time lag between the start of hydraulic fracturing and presence of natural gas in groundwater wells.
- Their study shows a need for additional methane source identification techniques and continued monitoring to determine if hydraulic fracturing activity will result in natural gas or fracking fluid in groundwater over longer periods of time.

This study focused specifically on methane contamination and not the broader threats to water resources. Although the study findings appear to support the commenter's assertion that hydraulic fracturing is not a threat to drinking water, in view of the caveats noted above and contradictory evidence presented in this response to comments, such support is less than compelling.

Ladage, S., Blumenberg, M., Houben, G., Pfunt, H., Gestermann, N., Franke, D., Erbacher, J., 2016. Schieferöl und Schiefergas in Deutschland – Potenziale und Umweltaspekte [Shale oil and gas in Germany – Resources and environmental impacts], - Federal Institute for Geosciences and Natural Resources, Hanover, Germany,

NOTE: THIS STUDY IS ONLY AVAILABLE IN GERMAN. LINK: HTTPS://WWW.REUTERS.COM/ARTICLE/GERMANY-SHALE/GERMAN-STUDY-SAYS-DOMESTIC-SHALE-GAS-OIL-PRODUCTION-POSSIBLE-IDUSL8N15A2SN;

2017 ABSTRACT AVAILABLE AT HTTPS://MEETINGORGANIZER.COPERNICUS.ORG/EGU2017/EGU2017-13750.PDF.

THE AUTHORS ARE EMPLOYEES OF THE FEDERAL INSTITUTE FOR GEOSCIENCES AND NATURAL RESOURCES, HANOVER, GERMANY. THE SOURCE OF FUNDING FOR THE STUDY IS NOT AVAILABLE.

Based on computer simulations, geologists at the Federal Institute for Geosciences and Natural Resources (BGR) conducted an assessment of the potential resources and environmental impacts of shale gas development and hydraulic fracturing. The study included numerical hydrogeological modelling of hydraulic fracturing fluid migration in the subsurface and stress modeling to estimate fracturing dimension magnitudes and the potential frequency of induced seismicity. BGR found through simulations that hydraulic fracturing fluids injected into the bedrock of a North German basin (where major shale plays are expected) did not migrate from the target formation upwards into drinking water aquifers. The study concludes that the risk to groundwater is small if suitable locations are selected in compliance with legal regulations and using state-of-the-art technology. The scope of the study of impacts was limited to model simulations of conditions in bedrock formations of Germany and relates only to potential impacts resulting from the hydraulic fracturing stage and migration from the target formation. The study provides limited support to the conclusion that hydraulic fracturing is not a threat to drinking water resources.

Nicot, J., Mickler, P., Larson, T., Castro, M.C., Darvari, R., Smyth, R., Uhlman, K., Omelon, C., 2015. Understanding and Managing Environmental Roadblocks to Shale Gas Development: An Analysis of Shallow Gas, NORMs, and Trace Metals. Bureau of Economic Geology, The University of Texas at Austin, 271 p. https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/gwat.12508

NOTE: THIS STUDY IS LISTED IN THE API COMMENT AS "BUREAU OF ECONOMIC GEOLOGY, UNIVERSITY OF TEXAS AT AUSTIN, 2016." THE AUTHORS ARE ACADEMICIANS WITH THE UNIVERSITY OF TEXAS AT AUSTIN AND THE UNIVERSITY OF MICHIGAN (OTHER PARTICIPANTS INCLUDED INDIVIDUALS FROM ST. EDWARDS UNIVERSITY (AUSTIN, TX), AN ENVIRONMENTAL CONSULTING COMPANY AND THE TEXAS WATER CONTROL BOARD). THE STUDY WAS FUNDED BY THE RESEARCH PARTNERSHIP TO SECURE ENERGY FOR AMERICA (RPSEA).

The main objective of this study was to document occurrences of shallow gas in freshwater aquifers in Texas (either dissolved or free phase) and identify controlling processes. The study included the analysis of more than 900 water wells and found that methane is naturally occurring in many Texas aquifers at varying concentrations, but "only in the aggregate sense". The authors note documented, historic methane mobilization mechanisms (well integrity issues/water level drops/air drilling), and that ruling out oil and gas extraction activity as the primary cause of methane occurrence in a particular well cannot conclusively be done without further, detailed study. The authors recommend technological advancements in well casing as well as well venting systems as reasonable courses of action to address methane contamination of water wells. Regarding the extent to which oil and gas activities have contaminated water wells, the study is inconclusive, and, therefore, the study does not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources".

Siegel, D.I., Azzolina, N.A., Smith,B.J., Perry, A.E., and Bothun, R.L., 2015. Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania. Environmental Science & Technology, 2015, 49, p. 4106-4112. https://pubs.acs.org/doi/10.1021/es505775c

NOTE: THE AUTHORS INCLUDE AN ACADEMICIAN WITH SYRACUSE UNIVERSITY, AND EMPLOYEES OF THE CETER GROUP, ENVIRO CLEAN PRODUCTS AND SERVICES, AND AECOM. THE STUDY WAS FUNDED BY CHESAPEAKE ENERGY CORPORATION.

The objective of this study was to examine the relationship between dissolved methane in groundwater and proximity to oil and gas wells in northeastern Pennsylvania (Bradford, Susquehanna, Sullivan, Wyoming and other nearby counties), and to verify the findings of previous studies that reported dissolved methane concentrations up to six times higher in drinking water within 1 kilometer of a gas well, compared to concentrations in groundwater farther than 1 kilometer away. The study found no statistically significant relationship between dissolved methane concentrations in groundwater from domestic water wells and proximity to pre-existing oil or gas wells. Although the study appears to support the API assertion that "hydraulic fracturing is not a threat to drinking water," following publication, this article was the subject of an ethics review by the publishing journal (Environmental Science & Technology) for the authors' failure to disclose that Chesapeake Energy had funded the study (Banerjee, 2015). The authors later published a correction which clarified the funding source as Chesapeake Energy and further clarified author affiliations, including the disclosure of one of the author's employment with a consulting firm (Enviro Clean Products and Services) that did consulting work for Chesapeake Energy, and the same author's prior employment by Chesapeake Energy (Siegel *et al*., 2015c). The original article had included the statement "The authors declare no competing financial interest." Financial relationships can influence research outcomes in a variety of ways (Resnick and Elliott, 2013).

Jackson, R.B, Lowry, A.R., Pickle, A., Kang, M., DiGiulio, D., and Zhao, K., 2015. The Depths of Hydraulic Fracturing and Accompanying Water Use Across the United States, Environmental Science and Technology, 49(15), P. 8969-8976. https://pubs.acs.org/doi/abs/10.1021/acs.est.5b01228?journalCode=esthag

NOTE: THE STUDY AUTHORS ARE ACADEMICIANS FROM STANFORD, DUKE, AND OHIO STATE UNIVERSITIES. THE STUDY WAS FUNDED BY THE STANFORD UNIVERSITY SCHOOL OF EARTH, ENERGY, AND ENVIRONMENTAL SCIENCES, THE PRECOURT INSTITUTE FOR ENERGY, AND THE WOODS INSTITUTE FOR THE ENVIRONMENT.

The goal of this 2015 study was to quantify the depths of hydraulic fracturing in the United States and to analyze the water used for hydraulic fracturing. The study suggested that, because hydraulic fractures can propagate 2000 ft upward, shallow wells may warrant special safeguards, including a mandatory registry of locations, full chemical disclosure, and, where horizontal drilling is used, pre-drilling water testing to a radius of 1000 feet beyond the greatest lateral extent. The study found that:

- Average fracturing depth across the United States was 8300 ft (~2500m).
- Many wells (6900; 16 percent) were fractured less than a mile below the surface, and 2600 wells (6 percent) were fractured at depths less than 3000 ft (900 m).
- Average water use per well nationally was 2,400,000 gallons (in Pennsylvania, 4,500,000 gallons).
- Even fractures that do not extend all the way to an overlying aquifer can link formations by connecting them to natural faults, fissures, or other pathways. In British Columbia, a special permit is required if hydraulic fracturing is to occur at depths above 600 m (~2000 ft).
- In PA, where FracFocus reporting is voluntary, the distribution of wells included in the study database is neither comprehensive nor representative of all wells drilled in the state. For these reasons, the occurrence of shallow hydraulic fracturing across the United States is underestimated in this study's analysis.

The scope of the study did not include any analysis of environmental impact. This study does not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources".

Drollette, B.D., Hoelzer, K., Warner, N., Darrah, T.H., Karatume, O., O'Connor, M.P., Nelson, R.K., Fernandezg, L.A., Reddy, C.M., Vengosh, A., Jackson, R.B., Elsner, M., and Plata, D.L., 2015. Elevated levels of diesel range organic compounds in groundwater near Marcellus gas operations are derived from surface activities. PNAS 112(43), October 27, 2015, 6 P. https://www.pnas.org/content/112/43/13184

NOTE: THE AUTHORS ARE ACADEMICIANS WITH YALE UNIVERSITY, THE INSTITUTE OF GROUNDWATER ECOLOGY, HELMHOLTZ ZENTRUM MÜNCHEN (GERMANY), PENNSYLVANIA STATE UNIVERSITY, THE OHIO STATE UNIVERSITY, DUKE UNIVERSITY, NORTHEASTERN UNIVERSITY, AND STANFORD UNIVERSITY. THE STUDY WAS FUNDED BY DUKE UNIVERSITY'S PRATT SCHOOL OF ENGINEERING AND THE NATIONAL SCIENCE FOUNDATION.

This 2015 study set out to determine whether existing levels of specific organic compounds (gasoline- and diesel-related) found in drinking water aquifers above the Marcellus Shale and other shale plays were the result of natural geologic transport processes (i.e., hydraulic connectivity between formations) or contamination from anthropogenic activities, including enhanced natural gas production. The study paired the analysis of organic compounds with inorganic chemical fingerprinting, noble gas analysis, and spatial relationships between active shale gas extraction wells and wells with disclosed environmental health and safety violations. The study found that the dominant source of organic compounds in shallow aquifers was consistent with accidental surface spills or leaks of HVHF chemicals. Although the study did not find evidence for direct communication of deeper formation water or injected fracturing fluids with shallow drinking water wells due to upward migration from shale horizons, the study did link the presence of contaminants with HVHF activity (chemical handling resulting in surface releases from spills or leaks). The study does not support the claim that hydraulic fracturing is not a threat to drinking water.

Siegel, D., Smith, B., Perry, E., Bothun, R., and Hollingsworth, M., 2016. Dissolved methane in shallow groundwater of the Appalachian Basin: Results from the Chesapeake Energy predrilling geochemical database, Environmental Geosciences, 23(1), p. 1-47. http://archives.datapages.com/data/deg/2016/EG012016/eg15015/eg15015.html?doi=10.1306%2Feg.01051615015

NOTE: THE AUTHORS INCLUDE AN ACADEMICIAN WITH SYRACUSE UNIVERSITY, AND EMPLOYEES OF ENVIRO CLEAN PRODUCTS AND SERVICES, AECOM, AND CHESAPEAKE ENERGY CORPORATION. THE STUDY WAS FUNDED BY CHESAPEAKE ENERGY CORPORATION.

The objective of this 2016 study was to scientifically resolve the degree to which dissolved methane naturally occurs in shallow groundwater overlying the Marcellus and Utica Shale plays, with the expectation that a much larger set would provide more clarity than smaller data sets that are not as geographically dense. The study indicates that natural methane commonly occurs in the Appalachian Basin groundwater. This large data set (analytical results for 19,278 predrilling groundwater samples) showed that dissolved methane in shallow groundwater in northeast Pennsylvania commonly occurs in sodium-dominated groundwater types and originates from the surrounding and underlying rocks or from deeper connate brines commonly found in valley settings at shallow depths. While the study appears to support the API comment that "hydraulic fracturing is not a threat to drinking water resources," the study was supported and funded by Chesapeake Energy, and the conflict of interest statement preceding the article occupies most of the first page. This statement includes the disclosure that one of the authors was employed by Chesapeake Energy, maintained the data set used in the study, and owned stock in the company in an amount in excess of $5000. Financial relationships can influence research outcomes in a variety of ways (Resnick and Elliott, 2013).

CCST (California Council on Science & Technology). (2015a). "An Independent Scientific Assessment of Well Stimulation in California–Executive Summary-An Examination of Hydraulic Fracturing and Acid Stimulations in the Oil and Gas Industry, July 2015." https://ccst.us/wp-content/uploads/2015SB4-v2ES.pdf

NOTE: THE STUDY IS LISTED IN THE API COMMENT AS "BIRKHOLZER *ET AL.,* 2015." THE AUTHORS ARE EMPLOYEES OF THE CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY AND THE LAWRENCE BERKELEY NATIONAL LABORATORY. THE STUDY WAS FUNDED BY THE CALIFORNIA NATURAL RESOURCES AGENCY.

This is a 21-page executive summary to an independent 2015 scientific study to assess current and potential future well stimulation practices in California, including: the likelihood that these technologies could enable extensive new petroleum production in the state; the impacts of well stimulation technologies (including hydraulic fracturing, acid fracturing and matrix acidizing) and the gaps in data that preclude this understanding; potential risks associated with current practices; and alternative practices that might limit these risks. The study includes water, air and occupational risks. The water-related conclusions shown below indicate potential risks and a lack of data to show current exposure.

Water-related Conclusions

- The California experience with hydraulic fracturing differs from that in other states.
- Hydraulic fracturing in California does not use a lot of fresh water compared to other states and other human uses. This is because California wells tend to be shallow and the reservoirs more permeable and California operators generally do not conduct high volume hydraulic fracturing from long-reach horizontal wells.
- The shallow oil wells could cross contaminate shallow aquifers.
- Direct impacts of hydraulic fracturing stem from unrestricted chemical use but appear small and have not been investigated. Operators have unrestricted use of many hazardous and uncharacterized chemicals in hydraulic fracturing. These need to be studied to determine true direct impacts.
- The majority of impacts associated with hydraulic fracturing are caused by the indirect impacts of oil and gas production enabled by hydraulic fracturing, though this applies to all oil and gas development, not just hydraulic fracturing.
- Oil and gas development causes habitat loss and fragmentation.
- Produced water could contain hydraulic fracturing chemicals, which have not been measured. These are sometimes reused (e.g., agriculture) without proper testing and treatment.
- Injection wells currently under review for inappropriate disposal into protected aquifers may have received water that contains chemicals from hydraulic fracturing.
- Disposal of produced water by underground injection has caused earthquakes elsewhere. These need to be further investigated for California.
- Shallow fracturing raises concerns about potential groundwater contamination.
- Leakage of hydraulic fracturing chemicals could occur through existing wells.

This study shows that fracturing could be a threat to drinking water. This study does not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources."

CCST (California Council on Science & Technology). (2015c). "An Independent Scientific Assessment of Well Stimulation in California – Summary Report – An Examination of Hydraulic Fracturing and Acid Stimulations in the Oil and Gas Industry, July 2015." 119 p.
https://ccst.us/wp-content/uploads/2015SB4summary.pdf

NOTE: THIS STUDY WAS LISTED IN THE API COMMENT AS "CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY (CCST), 2015." THE AUTHORS ARE EMPLOYEES OF THE CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY AND THE LAWRENCE BERKELEY NATIONAL LABORATORY. THE STUDY WAS FUNDED BY THE CALIFORNIA NATURAL RESOURCES AGENCY.

This is the 119-page full summary report of the independent 2015 scientific study to assess current and potential future well stimulation practices in California described above. (See conclusions above.)

The full report includes a table of environmental risks associated with hydraulic fracturing (Appendix F) that demonstrates a relatively high level of risk with the activity. Risk issues include:

- Number and toxicity of chemicals in hydraulic fracturing and acid stimulation fluids
- Shallow fracturing
- Hydraulic fracturing in reservoirs with long history of oil and gas production
- Spills and leaks
- Injection of recovered fluids and produced water into aquifers used for drinking, agriculture, and other direct and indirect uses by humans
- Beneficial use of produced water
- Disposal of water in percolation pits
- Acid use (not likely to be applied in shale formations)
- Oil and gas development near human populations
- Induced seismicity
- Loss of habitat

This study shows that fracturing could be a threat to drinking water. This study does not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources."

Hammack, R., Harbert, W., Sharma, S., Stewart, B., Capo, R., Wall, A., Wells, A., Diehl, R., Blaushild, D., Sams, J., Veloski, G., 2014. An Evaluation of Fracture Growth and Gas/Fluid Migration as Horizontal Marcellus Shale Gas Wells are Hydraulically Fractured in Greene County, Pennsylvania. NETL-TRS-3-2014; EPAct Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Pittsburgh, PA, 76 p. https://edx.netl.doe.gov/dataset/an-evaluation-of-fracture-growth-and-gas-marcellus-shale-gas-wells-greene-county-pa

NOTE: THE AUTHORS ARE EMPLOYEES OF THE NATIONAL ENERGY TECHNOLOGY LABORATORY AND ACADEMICIANS WITH THE UNIVERSITY OF PITTSBURGH AND WEST VIRGINIA UNIVERSITY. THE REPORT WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY AN AGENCY OF THE UNITED STATES GOVERNMENT.

This 2014 field study monitored the induced fracturing of six horizontal Marcellus Shale gas wells in Greene County, Pennsylvania. The study had two research objectives: 1) to determine the maximum height of fractures created by hydraulic fracturing at this location; and 2) to determine if natural gas or fluids from the hydraulically fractured Marcellus Shale had migrated 3,800 ft upward to an overlying Upper Devonian/Lower Mississippian gas field during or after hydraulic fracturing. Monitoring for evidence of fluid migration was performed during and after the hydraulic fracturing of six horizontal Marcellus Shale gas wells. This monitoring program included: 1) gas pressure and production histories of three Upper Devonian/Lower Mississippian wells; 2) chemical and isotopic analysis of the gas produced from seven Upper Devonian/Lower Mississippian wells; 3) chemical and isotopic analysis of water produced from five Upper Devonian/Lower Mississippian wells; and 4) monitoring for perfluorocarbon tracers in gas produced from two Upper Devonian/Lower Mississippian wells.

Current findings are: (1) no evidence of gas migration from the Marcellus Shale; and (2) no evidence of brine migration from the Marcellus Shale. Four perfluorocarbon tracers were injected with hydraulic fracturing fluids into 10 stages of a 14- stage, horizontal Marcellus Shale gas well during stimulation. Gas samples collected from two Upper Devonian/Lower Mississippian wells that directly overlie the tracer injection well were analyzed for presence of the tracer. No tracer was found in 17 gas samples taken from each of the two wells during the 2-month period after completion of the hydraulic fracturing.

Although this study appears to support the API comment that “hydraulic fracturing is not a threat to drinking water resources”, this study is limited in scope and location and relates only to potential short-term impacts resulting from the hydraulic fracturing stage and migration from the target formation.

Kresse, T.M., Warner, N.R., Hays, P.D., Down, A., Vengosh, A., Jackson, R.B., 2012. Shallow Groundwater Quality and Geochemistry in the Fayetteville Shale Gas-Production Area, North-Central Arkansas. USGS Scientific Investigations Report 2012–5273, 31 p.
https://pubs.usgs.gov/sir/2012/5273/

NOTE: THE AUTHORS INCLUDE AN EMPLOYEE OF THE U.S. GEOLOGICAL SURVEY AND ACADEMICIANS WITH DUKE UNIVERSITY. THE STUDY WAS SUPPORTED BY THE ARKANSAS NATURAL RESOURCES COMMISSION, ARKANSAS OIL AND GAS

COMMISSION, DUKE UNIVERSITY, FAULKNER COUNTY, SHIRLEY COMMUNITY DEVELOPMENT CORPORATION, THE UNIVERSITY OF ARKANSAS AT FAYETTEVILLE, AND THE U.S. GEOLOGICAL SURVEY GROUNDWATER RESOURCES PROGRAM.

This report presents the results of a 2011 USGS field study of the Fayetteville Shale in north-central Arkansas where approximately 4,000 producing natural gas wells were completed by April 2012 using horizontal drilling and hydraulic fracturing. In the study, 127 domestic water wells were sampled and analyzed for major ions and trace metals, with a subset of the samples analyzed for methane and carbon isotopes to describe general water quality and geochemistry and to investigate the potential effects of gas-production activities on shallow groundwater in the study area. Water quality analyses from this study were compared to historical (pre-gas development) shallow groundwater quality collected in the gas-production area. An additional comparison was made using analyses from this study of groundwater quality in similar geologic and topographic areas for well sites less than and greater than 2 miles from active gas-production wells. Groundwater-quality data collected for this study indicate that groundwater chemistry in the shallow aquifer system in the study area is a result of natural processes, beginning with recharge of dilute atmospheric precipitation and evolution of observed groundwater chemistry through rock-water interaction and redox processes. This study appears to support the API statement that "hydraulic fracturing is not a threat to drinking water resources," although this support is limited in that the scope of the study is limited to the north-central Arkansas study area.

Flewelling, S., and Sharma, M., 2013. Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine, Groundwater Online Journal, National Groundwater Association, July 2013. https://ngwa.onlinelibrary.wiley.com/doi/full/10.1111/gwat.12095

NOTE: THE AUTHORS ARE EMPLOYED BY GRADIENT, AN OIL AND GAS INDUSTRY CONSULTANT. THE STUDY WAS FUNDED BY HALLIBURTON ENERGY SERVICES, INC. CONTRARY TO THE API COMMENT, NO GOVERNMENT AGENCY OR ACADEMIC INSTITUTION WAS INVOLVED IN CONDUCTING THIS STUDY.

This 2013 journal article presents the results of a study on the potential upward migration of hydraulic fracturing fluid and brine to potable water aquifers. The study addresses concern regarding potential environmental effects associated with predictions of upward migration of hydraulic fracturing fluid and brine from hydraulically fractured black shales. This study refutes other studies (Rozell and Reaven 2012; Myers 2012; Warner, *et al*. 2012) that have suggested that such upward migration can be large and that timescales for migration can be as short as a few years.

This article discusses the physical constraints on upward fluid migration from black shales (e.g., the Marcellus, Bakken, and Eagle Ford) to shallow aquifers, taking into account the potential changes to the subsurface brought about by HF. Their review of the literature indicates that HF affects a very limited portion of the entire thickness of the overlying bedrock and therefore, is unable to create direct hydraulic communication between black shales and shallow aquifers via induced fractures. As a result, upward migration of hydraulic fracturing fluid and brine is controlled by preexisting hydraulic gradients and bedrock permeability. The article indicates that in cases where there is an upward gradient, permeability is low, upward flow rates are low, and mean travel times are long (often

>10^6 years). They conclude that the rapid upward migration scenarios that have been suggested are not physically plausible.

Although this study appears to support the API statement that "hydraulic fracturing is not a threat to drinking water resources," the study was not conducted by a government agency or academic institution as claimed by API, and it was funded by the oil and gas industry. Financial relationships can influence research outcomes in a variety of ways (Resnick and Elliott, 2013).

Molofsky, L.J., Connor, J.A., Wylie, A.S., Wagner, T., and Farhat, S.K., 2013. Evaluation of Methane Sources in Groundwater in Northeastern Pennsylvania, Groundwater 51(3) p. 333-349. https://onlinelibrary.wiley.com/doi/abs/10.1111/gwat.12056

NOTE: THE AUTHORS ARE EMPLOYEES OF GSI ENVIRONMENTAL, INC. (AN OIL AND GAS INDUSTRY CONSULTANT) AND CABOT OIL AND GAS CORPORATION. THE STUDY WAS FUNDED BY GSI ENVIRONMENTAL, INC. CONTRARY TO THE API COMMENT, NO GOVERNMENT AGENCY OR ACADEMIC INSTITUTION WAS INVOLVED IN CONDUCTING THIS STUDY.

This 2013 study focuses on the potential for methane impacts in drinking water wells located within areas of hydraulic fracturing activities for shale-gas development and reviews the potential sources of methane levels in drinking water wells in Susquehanna County in northeastern Pennsylvania. The study concludes that: *"methane is common in Susquehanna County water wells and is best correlated with topography and groundwater geochemistry, rather than shale-gas extraction activities."* Based upon data in Susquehanna County the findings of this specific study suggest that *"shale-gas extraction in northeastern Pennsylvania has not resulted in regional gas impacts on drinking water resources and that, in turn, the hydraulic fracturing process has not created extensive pathways by which gas from the Marcellus Shale could rapidly migrate into the shallow subsurface."* While the study appears to support the conclusion that "hydraulic fracturing is not a threat to drinking water resources" this study is limited to an evaluation of stray gas migration to surficial groundwater aquifers in one county. In addition, although API commented that these supporting studies were performed by "*government agencies and academic institutions*", the authors of this study were neither. Specifically, the authors of this study were employees of GSI Environmental, Inc. and Cabot Oil and Gas Corporation, and the study was funded by an oil and gas industry consultant.

Government Accountability Office, 2012. Oil and Gas Information on Shale Resources, Development, and Environmental and Public Health Risks, United States Government Accountability Office. https://www.gao.gov/assets/650/647791.pdf

NOTE: THE AUTHOR OF THIS REPORT IS THE GOVERNMENT ACCOUNTABILITY OFFICE. THE REPORT WAS REQUESTED BY THE U.S. CONGRESS AND FUNDED BY THE U.S. GOVERNMENT.

The purpose of this 2012 Report to Congress from the GAO, was to review available data from 2007 through 2011 and the environmental and public health risks associated with development of shale oil and gas. One of the overall conclusions of this study was that: *"the risks identified in the studies and publications we reviewed cannot, at present, be quantified, and the magnitude of potential adverse* *effects or likelihood of occurrence cannot be determined…"* Specifically, as it relates to water resources the study stated:

- "According to a number of studies and publications we reviewed, shale oil and gas development poses a risk to surface water and groundwater because withdrawing water from streams, lakes, and aquifers for drilling and hydraulic fracturing could adversely affect water sources."

- "Shale oil and gas development poses a risk to water quality from spills or releases of toxic chemicals and waste that can occur as a result of tank ruptures, blowouts, equipment or impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or operational errors."

- "Drill cuttings, if improperly managed, also pose a risk to water quality. Drill cuttings brought to the surface during oil and gas development may contain naturally occurring radioactive materials (NORM), along with other decay elements (radium-226 and radium-228)"

- The chemical additives in fracturing fluid, if not properly handled, also poses a risk to water quality if they come into contact with surface water or groundwater.

- The produced water and fracturing fluids returned during the flowback process contain a wide range of contaminants and pose a risk to water quality,

- According to a number of studies and publications we reviewed, underground migration of gases and chemicals poses a risk of contamination to water quality.

- A well that is not properly isolated through proper casing and cementing could allow gas or other fluids to contaminate aquifers as a result of inadequate depth of casing, inadequate cement in the annular space around the surface casing, and ineffective cement that cracks or breaks down under the stress of high pressures.

- If shale oil and gas development activities result in connections being established with natural fractures, faults, or improperly plugged dry or abandoned wells, a pathway for gas or contaminants to migrate underground could be created—posing a risk to water quality.

This study also references other ongoing federal studies including the EPA Drinking Water Study that was completed in 2016. This study does not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources."

(Cardno ENTRIX, 2012). Hydraulic Fracturing Study, PXP Inglewood Oil Field, Cardno ENTRIX, Los Angeles, CA, 206 p. https://www.eenews.net/assets/2012/10/11/document_ew_01.pdf

NOTE: THE AUTHOR OF THE REPORT IS CARDNO ENTRIX. THE APPARENT FUNDING SOURCE WAS PXP PLAINS EXPLORATION & PRODUCTION COMPANY.

This 2012 study was one of the outcomes of the settlement of a lawsuit against PXP and Los Angeles County related to the Inglewood oil field. Before-and-after monitoring of groundwater quality in monitor wells did not show impacts from high volume hydraulic fracturing. Methane analyzed in soil gas and groundwater showed no indication of impacts from high volume hydraulic fracturing. Data from the project indicate that the groundwater bearing zone is limited in extent and not suitable for a water supply that could serve the oil field or the surrounding community. None of the thin, discontinuous water-bearing zones within the Inglewood Oil Field connect to the aquifers of the Los Angeles Basin. The water was analyzed for pH, total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene, total xylenes, methyl tertiary butyl ether (MTBE), total recoverable petroleum hydrocarbons (TRPH), total dissolved solids (TDS), nitrate, nitrite, metals, and biological oxygen demand (BOD5). While the study appears to support the API comment that “hydraulic fracturing is not a threat to drinking water resources,” this support is weak. The study was limited to an evaluation of impacts to groundwater that is not a drinking water source. The geologic setting in the Los Angeles Basin is considerably different than that of the Delaware River Basin and the monitoring plan was limited to a few parameters, some of which may not indicate impacts related to hydraulic fracturing. Contrary to the API comment, the study was not conducted by a government agency or an academic institution. The study was apparently funded by an oil and gas production company.

Massachusetts Institute of Technology Energy Initiative, 2010. The future of natural gas: an interdisciplinary MIT study interim report. MIT Energy Initiative, 104 p. http://energy.mit.edu/research/future-natural-gas/

NOTE: THE STUDY PARTICIPANTS ARE ACADEMICIANS AND RESEARCH SCIENTISTS AT MIT. THE STUDY WAS FUNDED BY THE AMERICAN CLEAN SKIES FOUNDATION, A NATURAL GAS ADVOCACY GROUP FOUNDED BY A FORMER CEO AND CHAIRMAN OF CHESAPEAKE ENERGY. THE REPORT CITED IS AN INTERIM REPORT. THE URL CITED NOW LINKS TO THE FINAL REPORT. THE INTERIM REPORT WAS ACCESSED ON 8/9/20 AT HTTPS://WWW.CIRCLEOFBLUE.ORG/WP-CONTENT/UPLOADS/2010/08/MIT-REPORT-NATURAL-GAS.PDF

The objective of this 2010 study was to examine the role of natural gas in a carbon-constrained world, with a time horizon out to mid-century. The interim report provides little analysis of the risks of HVHF activity to water resources. The study focuses on energy needs and markets and only briefly notes some of the environmental risks associated with hydraulic fracturing. In the scheme of the present state of unconventional gas development, the report is dated. The dated content and different focus of this study do not support the conclusion that “hydraulic fracturing is not a threat to drinking water resources.”

Summary

The American Petroleum Institute cited 20 studies as "reputable studies by government agencies and academic institutions that, along with empirical evidence, lead one to conclude that hydraulic fracturing is not a threat to drinking water." An examination of these 20 studies, including the identification of author affiliations and funding sources, along with the findings of many other studies, lead the Commission to a different conclusion.

The API comment states that the 20 cited studies were conducted by government agencies and academic institutions. Three of the 20 studies were not conducted by a government agency or an academic institution. Six of the studies were funded by industry, industry consultants, or an industry advocacy group. Eleven of the studies do not support the conclusion that "hydraulic fracturing is not a threat to drinking water resources." Of the nine studies that appear to support this conclusion, five were funded by industry or industry consultants, and the support of the other four studies is limited by narrow geographic or investigative scope or uncertainty in findings.

Based on the review of the documentation of these 20 studies, and in consideration of the many other relevant and compelling studies referenced elsewhere in this document that were absent from the API comments, the Commission disputes API's conclusion that hydraulic fracturing is not a threat to drinking water.

APPENDIX-4 STATUTORY AND REGULATORY ACTIVITY RELATING TO UNCONVENTIONAL OIL AND GAS DEVELOPMENT IN PENNSYLVANIA (PROVIDED BY PENNSYLVANIA DEP)

2004-2007

- Unconventional gas well industry conducts exploratory drilling in PA subject to DEP's 1984 regulatory requirements for the conventional oil and gas industry.

2008

- 2008 Unconventional gas well development boom begins.
- DEP creates PA Clean Streams Law-based General Permit, "ESCGP-1," continuing the requirement that PA gas developers obtain erosion and sediment control permits after Congress passes exemptions at federal level.

2009

- DEP opens Williamsport Oil & Gas Program Office.
- Environmental Quality Board (EQB) promulgates final regulations to increase permit application fees to hire additional technical staff to handle increased workload. DEP hires approximately 137 new staff for the Oil & Gas Program from 2009-2011.
- DEP initiates a new regulatory package to modernize well construction standards.

2010

- EQB promulgates final regulations to codify requirement for erosion and sediment control permit-in wake of federal exemptions, amending 25 Pa. Code Ch. 102.
- EQB promulgates final regulations to address Total Dissolved Solids pollution from natural gas well wastewater, amending 25 Pa. Code Ch. 95.
- DEP initiates a new rulemaking package addressing surface activities associated with both conventional and unconventional gas development (Surface Activities Rulemaking), proposing to amend 25 Pa. Code Ch. 78.
- Gov. Rendell issues Pa. Exec. Order No. 2010-05, placing a moratorium on additional leasing for gas development on lands owned and managed by the DCNR.

2011

- DEP begins to receive electronic reporting of data from well operators
- DEP establishes a new deputate, the Office of Oil & Gas Management, with direct oversight of both central office and district office operations.

- 2011 EQB promulgates final regulations to update well construction standards to address, inter alia, gas migration risks, amending 25 Pa. Code Ch. 78.

2012

- General Assembly enacts Act 13 of 2012, (2012 Oil & Gas Act), updating DEP's oversight authority of oil and gas well development and preempting municipal authority to zone unconventional gas development activities.
- General Assembly enacts Act 9 of 2012 directing DEP and PA Emergency Management Agency (PEMA) to adopt emergency regulations requiring unconventional gas operators to plan and prepare for emergency response.
- DEP finalizes ESCGP-2, updating the permit for erosion and sediment control of earth disturbances associated with oil and gas activities.
- Pennsylvania legislature enacts a moratorium on drilling in the South Newark basin, to expire on January 1, 2018.

2013

- EQB promulgates final regulations authorized by Act 9 of 2012, related to emergency planning and response, amending 25 Pa. Code Ch. 78.
- DEP publishes Technical Guidance "Addressing Spills and Releases at Oil & Gas Well Sites or Access Roads," Document No. 800-5000-001.
- DEP announces new online oil and gas mapping tool to provide access to statewide data related to well location, status and permitting information.
- EQB proposes new oil and gas rulemaking package for conventional and unconventional gas well development ("Surface Activities Rulemaking"), which included a 90-day public comment period; 9 public hearings in all regions of the state with testimony from approximately 300 individuals; and 23,213 written comments.
- PA Supreme Court finds portions of Act 13 of 2012 unconstitutional, including the provision preempting municipal zoning of unconventional gas development.
- DEP finalizes amendments to the Air Quality General Permit (GP-5) for natural gas compression and processing facilities establishing emission limitations, and including leak detection and repair, emission control, recordkeeping and reporting requirements.

2014

- EQB promulgates final regulations to increase permit application fees for gas wells, for DEP to hire additional staff in light of declining revenues and increasing workloads.
- DEP hires approximately 24 new staff to Oil & Gas Program.
- Gov. Corbett issues Pa. Exec. Order No. 2014-03, allowing additional leasing for oil and gas development on DCNR lands, rescinding Pa. Exec. Order No. 2010-5.
- General Assembly enacts Act 126 requiring regulations under the 2012 Oil & Gas Act to differentiate between conventional and unconventional wells. DEP bifurcates proposed Surface

Activities Rulemaking into two chapters: Ch. 78 (conventional wells) and 78a (unconventional wells).

- DEP launches e-Well permit to streamline oil and gas permitting process and allow the information to be accessed on DEP's webpage.
- General Assembly enacts Act 173 of 2014, the Unconventional Well Report Act, requiring operators to report production on a monthly basis.

2015

- Gov. Wolf issues Pa. Exec. Order No. 2015-03, reinstating the moratorium on additional gas leasing on DCNR lands, rescinding Pa. Exec Order No. 2014-03.
- DEP updates Technical Guidance: "Standards and Guidelines for Identifying, Tracking and Resolving Oil and Gas Violations," Document No. 820-4000-001.
- DEP publishes the TENORM report, analyzing the naturally occurring levels of radioactivity associated with unconventional gas development, leading to radioactive material action plan requirements to be included in the Surface Activities Rulemaking.
- EQB publishes the draft final Surface Activities Rulemaking for a second time, providing an additional 45-day public comment period; 3 additional public hearings, in the three oil and gas district office territories with testimony from 129 individuals; and 4947 additional written comments.
- DEP and DCNR fund expansion of a state seismic station network to record seismicity, in association with the Pennsylvania State University (PSU), in response to public concerns regarding induced seismicity from hydraulic fracturing and underground injection of oil and gas wastes. DEP's and DCNR's construction of the network expansion is completed in August 2016. PSU monitors network and maintains associated website.

2016

- Gov. Wolf announces Methane Reduction Strategy, which includes new requirements for oil and gas operators to reduce air emissions.
- Independent Regulatory Review Commission approves Ch. 78 and 78a rulemaking after full day hearing; House and Senate standing committees issue resolutions disapproving the rulemaking; General Assembly's Joint Committee on Documents holds hearing on the propriety of the regulatory process.
- General Assembly enacts Act 52 abrogating the Surface Activities Rulemaking - Ch. 78 (conventional wells); OAG directs DEP to strike Ch. 78 amendments.
- DEP releases eSubmission system for electronic submission of forms required from unconventional operators. eSubmission data is publicly available and searchable.
- DEP publishes interim final Technical Guidance "Guidelines for Implementing Area of Review Regulatory Requirement for Unconventional Wells," Document No. 800-0810-001, to address the potential risks of hydraulic fracturing in proximity to other wells.

- DEP publishes interim final Technical Guidance "Policy for the Replacement or Restoration of Private Water Supplies Impacted by Unconventional Operations," Document No. 800-0810-002, to inform DEP staff, industry and the public how to comply with the water supply restoration and replacement requirements in the 2012 Oil and Gas Act, The Clean Streams Law, and 25 Pa. Code Chapter 78a.
- EQB promulgates as final regulations the Ch. 78a Surface Activities Rulemaking for unconventional well development, modernizing and strengthening environmental protection for these activities.
- One week after EQB promulgates final Ch. 78a Surface Activities regulations, the Marcellus Shale Coalition files a lawsuit to enjoin portions of the new regulations.
- PA Commonwealth Court temporarily enjoins DEP's enforcement of portions of the Surface Activities regulations in response to the Marcellus Shale Coalition's lawsuit.

2017

- With the support of Gov. Wolf and the Governors of New York and Delaware, the Delaware River Basin Commission adopts a Resolution for the Minutes directing the Executive Director no later than November 30, 2017 to prepare and publish for comment draft regulations that prohibit "production of natural gas utilizing horizontal drilling and hydraulic fracturing within the [Delaware River] Basin."
- DEP publishes interim final Technical Guidance "Guidelines for Chain Pillar Development and Longwall Mining Adjacent to Unconventional Wells," Document No. 800-08 l 0-004, to facilitate appropriate unconventional well inactivation and re-entry procedures before and after longwall panel removal.
- DEP establishes "The Pipeline Portal" on DEP webpage providing public access to pipeline permit application and enforcement information.
- Pennsylvania legislature repeals the expiration date of the moratorium on drilling in the South Newark basin, effectively extending the moratorium indefinitely.

2018

- DEP finalizes ESCGP-3, updating the permit for erosion and sediment control of earth disturbances associated with oil and gas activities.
- DEP establishes the Office of Regional Permit Coordination as the lead office related to pipeline environmental permitting and enforcement.
- PA Supreme Court lifts portions of 2016 preliminary injunction of Ch. 78a Surface Activities Rulemaking, allowing DEP to implement most of the new regulations.
- DEP updates the Air Pollution Control Act General Permit GP-5 and finalizes a new General Permit GP-5a regulating emissions from unconventional gas well site operations and remote pigging operations.
- DEP releases Mechanical Integrity Assessment dataset (thousands of well assessments dating back to 2014) and an accompanying report.

2019

- EQB approves proposed regulations to control and reduce Volatile Organic Compound emissions (and thereby reduce methane emissions) from oil and gas development activities, amending 25 Pa. Code Ch. 127.

2020

- EQB approves final regulation to increase permit application fees for unconventional wells to fund retention of DEP staff complement in light of decreasing revenues and increasing workloads.
- DEP publishes draft Technical Guidance "Guidelines for Development of Operator Pressure Barrier Policy for Unconventional Wells," Document No. 800-0810-003, to facilitate appropriate well control incident risk mitigation.