Tracy Carluccio

Please find attached 3 PDFs -
1. Delaware Riverkeeper Network Comment Re. Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations; Proposed revisions and additions to section 18 CFR 401.35 relating to project review classifications. (145 pages, 1.1 MB)
2. Attachment 1 - Six Expert Reports (80 pages, 3.5 MB)
3. Attachment 2 - Curriculum Vitae for Experts (78 pages, 1.0 MB)

Thank you,
Tracy Carluccio
Delaware Riverkeeper Network

March 30, 2018

Commission Secretary
Delaware River Basin Commission
P.O. Box 7360
25 State Police Drive
West Trenton, NJ 08628-0360

Re: Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations; Proposed revisions and additions to section 18 CFR 401.35 relating to project review classifications

Dear Commission Secretary and Commissioners,

The Delaware Riverkeeper Network (DRN) submits these comments regarding the Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations; Proposed revisions and additions to section 18 CFR 401.35 relating to project review classifications ("Proposed Rules") that were publicly noticed by Delaware River Basin Commission (DRBC) on November 30, 2017.

I. THE DELAWARE RIVERKEEPER NETWORK

DRN is a non-profit organization established in 1988 to protect and restore the Delaware River, its associated watershed, tributaries, and habitats. This area includes 13,539 square miles, draining parts of New Jersey, New York, Pennsylvania and Delaware, and it is

DELAWARE RIVERKEEPER NETWORK
925 Canal Street, Suite 3701
Bristol, PA 19007
Office: (215) 369-1188
fax: (215)369-1181
drn@delawareriverkeeper.org
www.delawareriverkeeper.org

within this region that a portion of the Project's construction activity and operations will take place.

The Upper Delaware River is a federally designated "Scenic and Recreational River" administered by the National Park Service. The National Wild and Scenic Rivers System also includes large portions of the Lower Delaware and the Delaware Water Gap. The Lower, Middle and Upper Delaware River have high water quality and are subject to Delaware River Basin Commission Special Protection Waters Designation. The Basin and River are home to a number of federal and state listed endangered or threatened species including, but not limited to, the dwarf wedgemussel, Indiana bat, Timber Rattle snakes, bog turtle, Northeastern bulrush. Over 200 species of migratory birds have been identified within the drainage area of the Upper Delaware River within the Basin, including the largest wintering population of bald eagles within the Northeastern United States. The ecologically, recreationally and economically important American Shad population migrates up through the nontidal portions of the Delaware River to spawn, American Shad populations in the Delaware River are currently at depressed numbers. Migratory birds breed in or migrate through the high quality riparian corridors of the Basin. The Delaware River is also home to dozens of species of commercially and recreationally important fish and shellfish species.

In its efforts to protect and restore the watershed, DRN organizes and implements stream, wetland and habitat restorations, a volunteer monitoring program, educational programs, environmental advocacy initiatives, recreational activities, and environmental law enforcement efforts throughout the entire Delaware River Basin. DRN is a membership organization headquartered in Bristol, Pennsylvania, with more than 20,000 members with interests in the health and welfare of the Delaware River and its watershed. DRN is uniquely qualified to comment on and provide relevant information concerning associated impacts to human health and the environment.

These comments include and reflect the findings of technical experts engaged by DRN to analyze and comment on the Proposed Rules. All reports are submitted with these comments and are appended to this document.

Delaware Riverkeeper Network supports DRBC's proposal for the prohibition of high volume hydraulic fracturing (HVHF) in hydrocarbon bearing rock formations within the Delaware River Basin ("the Basin"). We provide more detail and additional recommendations regarding the prohibition under DRN's Section 440.3 comments and the proposed revisions and additions to section 18 CFR 401.35 relating to project review classifications under Section 3.8 of the Compact. These comments conclude that the prohibition is essential to provide needed protection to the Delaware River Watershed, but that it must go further.

DRN opposes the diversion, transfer or exportation of water from sources within the Basin of surface water, groundwater, treated wastewater or mine drainage water for utilization in hydraulic fracturing ("fracking") of hydrocarbon carbon bearing rock formations outside the Basin as proposed at Section 440.4. These comments conclude that the water export proposal constitutes a failure of the DRBC to protect the water resources of the Delaware River Basin. We provide more detail and additional recommendations regarding the prohibition under DRN's Section 440.4 comments.

DRN opposes the importation, transfer, treatment, storage, disposal, or discharge in the Basin of produced water and Centralized Waste Treatment (CWT) wastewater generated by fracking operations, as proposed at Section 440.5. These comments conclude that the wastewater proposal constitutes a failure of the DRBC to protect the water resources of the Delaware River Basin. We provide more detail and additional recommendations regarding the prohibition under DRN's Section 440.5 comments.

DRN respectfully requests the DRBC remove all reference to the allowance of water exports from the Basin for fracking and the import and storage, processing, disposal and discharge of CWT wastewater and produced water from fracking in the Basin, as described at Sections 440.4 and 440.5. DRN also requests that Section 440.3(b) is expanded to include prohibition of the activities related to fracking, specifically including the export of water and water resources out of the Basin for fracking elsewhere and the prohibition of the importation, transfer, treatment, storage, disposal, or discharge in the Basin of produced water and Centralized Waste Treatment (CWT) wastewater generated by fracking operations.

The Delaware River's waters are protected under the terms of the Delaware River Compact, the DRBC's Special Protection Waters Program, and regulations adopted in its Comprehensive Plan and Rules of Practice and Procedure. The Proposed Rules at Sections 440.4 and 440.5 fail to ensure protective management of the water resources of the Delaware River. DRN supports a complete ban on fracking and its activities, including a ban on water export out of the Basin for fracking and the import and storage, processing, disposal, and discharge of wastewater produced by fracking in the Basin.

DRN engaged six experts to review and assess the Proposed Rules, develop conclusions and make recommendations. These comments incorporate and rely upon the comments, recommendations and conclusions of these expert reports. The expert reports are submitted as Attachment 1. The curriculum vitae for these experts are collectively submitted as Attachment 2. DRN also relied upon information referenced in DRN's comment letter, documented by Endnotes and References.

LEGAL FRAMEWORK

a. Delaware River Basin Compact

Under the Delaware River Basin Compact of 1961, the DRBC is charged with conserving and managing the water resources of the Delaware River and its watershed.

Article 13, Section 13.1 of the Compact provides for the development and adoption, and periodic review and revision, of a Comprehensive Plan "for the immediate and long range development and use of the water resources of the basin. The plan shall include all public and private projects and facilities which are required, in the judgment of the commission, for the optimum planning, development, conservation, utilization, management and control of the water resources of the basin to meet present and future needs."

The DRBC implements the Compact's directives and objectives and the Comprehensive Plan through the Water Code and the Administrative Manual: Rules of Practice and Procedure ("RPP") (codified at 18 CFR §§ 401.81–90).

Article 3, Section 3.8 of the Delaware River Basin Compact requires that

> No project having a substantial effect on the water resources of the basin shall hereafter be undertaken by any person, corporation, or governmental authority unless it shall have been first submitted to and approved by the commission, subject to the provisions of Sections 3.3 and 3.5. The Commission shall approve a project whenever it finds and determines that such project would not substantially impair or conflict with the Comprehensive Plan and may modify and approve as modified, or may disapprove any such project whenever it finds and determines that the project would substantially impair or conflict with such Plan. The Commission shall provide by regulation for the procedure of submission, review and consideration of projects, and for its determinations pursuant to this section. Any determination of the Commission hereunder shall be subject to judicial review in any court of competent jurisdiction.

See also 18 C.F.R. § 401.32.

b. Comprehensive Plan

Sections 3.2 and 13.1 of the Compact require the creation of a Comprehensive Plan, which binds private parties and agencies to the Commission's vision for immediate and long term development within the Basin. Compact §§ 3.2, 13.1. The Commission has created a Comprehensive Plan which seeks to optimize the conservation, control, and management of the Basin's limited water resources and determine what type of development is consistent with the public interest. DRBC, *Comprehensive Plan* § I.A.b.; I.A.d. (July 2001). Activities which may have a substantial impact on the Basin are examined in the context of this Plan, and in order for a project to be approved by the DRBC, the Commission must determine that the project "provide[s] beneficial development of the water resources in a given locality or region,…the project conforms with accepted public policy," and the project does "not adversely influence the development of the water resources of the basin." *Id.* § I.A.d.

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. The Commission must also consider if there are particularly fragile areas of the Basin, such as Special Protection Waters, where a particular activity should *not* occur. *Wayne Land & Mineral Grp., LLC v. Delaware River Basin Comm'n*, No. 3:16-CV-00897 (M.D. Pa. Mar. 23, 2017), ECF No. 22-1.

c. <u>The Water Code</u>

DRBC's Water Code requires the conservation of the Basin's water resources, a consideration of present and future public interest when planning groundwater withdrawal projects, and the maintenance of basin water quality, *inter alia*. *See, e.g.*, Water Code §§ 2.20.2, 2.20.3, 2.20.5, 2.200.1; 18 C.F.R. § 410.1.

Section 3.40 of the Water Code regulates groundwater quality and requires its maintenance "in a safe and satisfactory condition…" Water Code § 3.40.3A. Section 3.40.4(B) explains that "[i]t is the policy of the Commission to prevent degradation of ground water quality" and that "[n]o quality change will be considered which…may be injurious to any designated present or future ground or surface water use." *Id.* §§ 3.40.4.

Similarly, 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. *Id.* §§ 2.20.2, 2.20.3.

The Water Code also protects the areas of the Delaware River and its tributaries that have exceptionally high water quality, known as Special Protection Waters. *Id.* § 3.10.3.2 *et seq*. Marcellus Shale natural gas deposits in the Basin are found *exclusively* within the area designated as Special Protection Waters. *Wayne Land & Mineral Grp., LLC v. Delaware River*

Basin Comm'n, No. 3:16-CV-00897 (M.D. Pa. Mar. 23, 2017), ECF No. 22-1. Section 3.10.3A.2.b. of the Water Code protects these waters "at their existing water quality." *Id.* § 3.10.3A.2.b. Additionally, the Water Code recognizes the need to protect water quality for other, nonhuman users, stating that "[t]he quality of the Basin waters shall be maintained in a safe and satisfactory condition for…wildlife, fish, and other aquatic life." *Id.* § 2.200.1.

Natural gas extraction and its related activities have the potential to negatively affect ground and surface water, and as such, are subject to regulation under the DRBC's Water Code.

d. <u>Rules of Practice and Procedure</u>

Section 1.2(g) of the Compact defines a "project" as including any work or activity identified by the Commission. Compact § 1.2(g). The DRBC's Rules of Practice and Procedure ("RPP"), published at 18 C.F.R. Part 401, establish thresholds under which Compact Section 3.8 project reviews take place. The following are sections of the RPP which grant DRBC the authority and duty to review natural gas development activities.

A project is subject to Commission review when the Executive Director "specially direct[s] by notice to the project sponsor or land owner as having a potential substantial water quality impact on waters classified as Special Protection Waters." *Id.* § 401.35(b)(18). The Executive Director has determined that *all* natural gas development projects may have a substantial effect on water resources of the Basin.

Additionally, RPP Sections 2.3.5A and 2.3.5C allow federal agencies such as the U.S. Fish and Wildlife Service and the National Park Service to refer projects to the Commission for review. 18 C.F.R. §§ 401.35(a), (c) (RPP §§ 2.3.5.A, C). Citing the need to protect the Basin's water quality and natural gas development's potential adverse effects, both the U.S. Fish and Wildlife Service and the National Park Service referred all projects that involve the development of natural gas wells to the DRBC for project review. *Wayne Land & Mineral Grp., LLC v. Delaware River Basin Comm'n*, No. 3:16-CV-00897 (M.D. Pa. Mar. 23, 2017) ECF No. 33-1, 2. The Commission *must* take action under Section 3.8 of the Compact once it receives such a referral. 18 C.F.R. § 401.35(c).

In addition to the DRBC's need to review natural gas well development when referred by an agency such as the U.S. Fish and Wildlife Service or the National Park Service, the Commission must review projects that "have or may have a substantial effect on the water resources of the basin" or that result in the discharge of pollutants into surface or ground waters of the Basin. *Id.* §§ 401.35(b), (b)(6).

Some natural gas development activities are also explicitly subject to Commission review; natural gas transmission lines and appurtenances are reviewed when "they would pass in, on, under or across an existing or proposed reservoir or recreation project area as designated in the Comprehensive Plan; [or] such lines would involve significant disturbance of ground cover affecting water resources;…" *Id.* § 401.35(a)(12). Natural gas pipelines are also subject to review under § 401.35(b)(7). *Id.* § (b)(7). In these instances the Commission directly recognizes that the disturbance of ground cover affects water resources.

Both water quantity and water quality are indisputably at issue with natural gas development.

e. <u>DRBC's Special Protection Waters Program</u>

The Delaware Riverkeeper Network petitioned the Delaware River Basin Commission (DRBC) in 1990 to develop a program to protect the exceptional water quality and outstanding resources of the designated Wild and Scenic Delaware River pursuant to the Outstanding Natural Resource Waters (ONRW) provision of the federal Clean Water Act.

In response, the DRBC amended its Water Code to include its unique version of ONRW, the Special Protection Waters program. In 1992 the DRBC granted the Upper and Middle Delaware Wild and Scenic River segments Outstanding Basin Waters status under their Special Protection Waters (SPW) program.

In 2001, after the Lower Delaware River was designated by Congress as Wild and Scenic, DRN again petitioned DRBC to classify the Lower Delaware River as SPW. As a result of DRN's efforts, the DRBC permanently designated the Lower Delaware River as Significant Resource Waters, a type of SPW, in July 2008.

The entire non-tidal Delaware River is protected by Special Protection Waters anti-degradation regulations. This designation requires strict regulation to protect the water quality of all SPW waters, which is documented as "exceptional" through regular water quality testing by the DRBC. The agency must maintain the high existing water quality so that there is **"no measurable change"** except towards natural conditions. Water Code § 3.10.3 *et seq.* codifies the anti-degradation program of the DRBC's Special Protection Waters program. (DRBC Resolution Nos. 70-3, 92-21, 94-2, 2008-9); *see also* 18 C.F.R. Part 410; Water Code §2.200.1*(*Resolution No. 67-7*)*("[t]he quality of Basin waters shall be maintained in a safe and satisfactory condition for...wildlife, fish and other aquatic life"); Water Code §2.20.2 ("[t]he 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 §2.20.5 ("[n]o 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 §3.40.4.B ("[i]t is the policy of the Commission to prevent degradation of ground water quality.…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").

The Draft Regulations fail to ensure that there will be no measurable adverse change to the quality of the Basin's water resources.

f. National Environmental Policy Act

The National Environmental Policy Act ("NEPA"), the nation's bedrock environmental law, seeks to ensure sound policy making by requiring that federal agencies evaluate the potential adverse impacts of their proposed activities before undertaking them. To achieve this goal, NEPA requires the preparation of an environmental impact statement for all "major Federal actions significantly affecting the quality of the human environment." 42 U.S.C. § 4332(2)(C). There can be no doubt that the DRBC is a federal agency subject to the requirements of NEPA. The language of the DRBC Compact itself provides that the Commission is a federal agency and thus subject to NEPA, stating that the "compact shall not enlarge the authority of any federal agency other than the commission." DRBC Compact, §15.1(o) (emphasis added). The Council on Environmental Quality's ("CEQ") regulations for NEPA also recognize DRBC as one of the "federal or federal-state agencies with jurisdiction by law" over NEPA issues, alongside the United States Environmental Protection Agency and numerous other federal agencies. NEPA Implementation Procedures, Appendix II, 49 Fed. Reg. 49750 (December 21, 1984).

Further, the issuance of regulations governing hydraulic fracturing activities within the Delaware River Basin is plainly a major federal action for purposes of NEPA. The CEQ regulations define a "major federal action" as an action "with effects that may be major and which are potentially subject to Federal control and responsibility," and such an actions involve "new and continuing activities, including projects and programs entirely or partly financed, assisted, conducted, regulated, or approved by federal agencies; new or revised agency rules, regulations, plans, policies, or procedures . . ." 40 C.F.R. § 1508.18. By this definition, the issuance of these regulations is clearly a major federal action because it creates a new program that adopts new agency rules and regulations, and is partly financed, regulated and approved by the DRBC and by the Army Corps of Engineers, the DRBC's federal member.

Moreover, for all the reasons set forth below and in the accompanying expert reports, the regulation of hydraulic fracturing within the Delaware River Basin is an activity that has the potential to have significant environmental effects. As such, it is evident that the DRBC is bound, subject to NEPA, to prepare a full environmental impact statement ("EIS") evaluating the range of potential adverse environmental impacts of its proposed regulatory program before issuing new regulations governing gas development within the Basin. 42 U.S.C. § 4332(2)(C); 40 C.F.R. §§ 1502.4, 1508.18. Nonetheless, the DRBC has issued its draft regulations without undertaking any NEPA environmental review measures whatsoever.

The purpose and benefits of NEPA's requirements are clear. NEPA's EIS requirement aims "to ensure both that an agency has information to make its decision and that the public receives information so it might also play a role in the decisionmaking process." *Dep't. of Transportation v. Public Citizen*, 541 U.S. 752 (2004). The statute is intended to insure that environmental concerns are integrated into the very process of agency decision-making. *Andrus v. Sierra Club*, 442 U.S. 347 (1979); *Lower Alloways Creek Tp. v. Public Service Elec. & Gas Co.*, 687 F.2d 732 (3d Cir. 1982). When the federal government conducts an activity, NEPA imposes procedural requirements to ensure that in making decisions, an agency will have available, and will carefully consider, detailed information concerning environmental impacts. To issue detailed regulations for new gas development in the Delaware River Basin without having reviewed the potential environmental impacts that may result therefrom is not only short-sighted but unlawful, and is likely to result in flawed and incomplete regulation of this risky industrial activity.

g. Cumulative Impacts Analysis

Adequate regulations based on a comprehensive environmental assessment are essential to protect the water supply for over 15 million people and to assure that the

Delaware River's Special Protection Waters (SPW) and all the Basin's water resources are protected from pollution and degradation. The Commission's Draft Regulations do not achieve the goal of preventing pollution, avoiding degradation, and helping to improve where needed the water resources of the Basin.

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 (USGS) 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.

The Commission's Water Resources Program FY2010-2015 (WR Program) calls for the Commission to "Perform Cumulative Impact Analysis on water supply 2011-2012 Funding permitting" (DRBC 2010b, p. 17) under its Natural Gas Development regulation program. The lack of a cumulative impact analysis undermines the Commission's ability to implement effective and sufficiently protective regulations. The Commission's WR Program states that "Additional demand for use in energy exploration, e.g. natural gas drilling, is increasing, although the full effect of this demand sector has yet to be identified" (DRBC 2010b, p.4) and "There will need to be more analysis of the water needs for energy projects and energy needs for water treatment as well as an evaluation of the carbon and water footprints" (DRBC 2010b p.11).

The impacts of hydraulic fracturing activities on the subsurface geology and ground water resources in the Delaware River Watershed are unknown and have not been studied or modeled by the Commission or any other agency. A cumulative impact analysis or environmental study should be completed to assess the subsurface changes that would occur and the resulting environmental impacts.

There is tremendous debate over the safety of hydraulic fracturing activities. The large number of incidents of pollution, methane gas migration, blowouts and other problems throughout Pennsylvania is well documented by PADEP. (*see* www.dep.state.pa.us/dep/deputate/minres/oilgas/OGInspectionsViolations/OGInspviol.htm).

One of the most disturbing aspects of the Draft Regulations is the obvious lack of information about the watershed and the lack of data about the expected impact. This information, gathered through an impact analysis, would serve as a foundation for the decision-making process and regulations. It is surprising that, in an area of high ecological importance and the presence of powerful economic interests (New York City, Philadelphia, utilities and the mining industry), there is no comprehensive model of the watershed allowing for the simulation of future scenarios.

Unfortunately, the Commission issued draft natural gas regulations without the benefits of the findings of such a study. 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. We consider the Draft Regulations lacking in the critical limits and management policies that this analysis would provide. In addition to specific deficiencies detailed in this comment, this is an inescapable fatal flaw in the Draft Regulations.

Proposed Regulatory Changes Sections 403.3, 440.4, and 440.5

This comment submission examines the proposed regulatory changes in three parts:

- the prohibition of high volume hydraulic fracturing (HVHF) in hydrocarbon bearing rock formations within the Basin;
- the export of water and water resources outside of the basin for fracking elsewhere;
- the import and storage, processing, disposal, and discharge of wastewater produced by fracking in the Basin.

Comment in Support of the Prohibition of HVHF at Section 440.3 (a) and (b)

DRN supports the complete prohibition of fracking throughout the Delaware River Watershed.

Marcellus and Utica Shale geologic formations underlie approximately 40% of the Basin, primarily in Pennsylvania and New York (a small portion of the Utica underlies the northwestern corner of New Jersey). These shales are considered the largest petroleum-producing deposits in the nation; approximately 5% of the total area of the Marcellus underlies the Delaware River Basin. (Schmid & Company, Inc., "Comments on Proposed

Regulations of the Delaware River Basin Commission Concerning High Volume Hydraulic Fracturing to Produce Oil and Gas, 3.18.2018). New Jersey and Pennsylvania also contain the South Newark Basin gas-bearing rock formation, identified by the U.S. Geologic Survey as potentially productive, although it is not being developed at this time. The potential for substantial adverse impacts from development of shale gas within the Basin is enormous.

The entire non-tidal Delaware River is protected by 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 existing water quality be maintained so that there is **"no measurable change"** except towards natural conditions. Approximately 50% of SPW are located in Pennsylvania, 35% in New York, and 15% in New Jersey. (Schmid) Of the SPW sections of the Basin, approximately 98% is underlain by Marcellus Shale in New York and 67% of the area in Pennsylvania. (Schmid). SPW designation applies to the entire watershed regions that drain to SPW waters. The anti-degradation provision of these waters would be unattainable if fracking were to occur in these regions due to the adverse impacts that accompany it.

Surface Development of Fracking Well Sites

The use of hydraulic fracturing to extract and develop natural gas from shale formations include several phases of the fracking process. The first stage is the development of the well site and adjacent operations which require the removal and clearing of vegetation and the reforming of the natural landscape. At this stage impacts include: destruction of vegetation; forest loss and forest fragmentation; soil compaction and destruction of the natural soil mantle and land contours; watershed drainage pattern alterations, and disruption of local hydrologic systems such as wetlands and vernal ponds.[i]

These impacts are part of the process of developing a gas well and are unavoidable, as found in a study of the potential impacts of fracking, based on the industry's practices since the modern shale boom began. "Disturbing the land is an unavoidable part of the fracking process to extract gas and move it to market. Specifically, well pads (generally taking up between 1-3 hectares) are needed to support equipment needed for drilling and fracking, access roads are required to bring equipment to the well pad, and gathering pipelines are needed to bring the gas from the well pad to an existing portion of the natural gas pipeline network."[ii]

The areas disturbed include the well pad; storage and ancillary equipment areas; freshwater basins or tanks and tanks or pits to store fracking fluid chemicals, flowback, produced water, fuel, and re-used or reusable frack fluids; containers to store proppants such as sand; driveways or access roads to the site; gathering pipelines, local compressors and related equipment to carry gas to a market pipeline; and in some instances, quarries for mining gravel for driveways and well pad pavement, and water lines, buried or on surface. The impacts of this activity can continue at varying levels during well drilling, stimulation, development, and production. Upon completion of construction activity, the invasion of non-native invasive species of plants into disturbed and cleared land and the transfer of destructive insects and pathogens result from the land use changes that have occurred at the well site. Compacted soil at the finished site can have a runoff coefficient close to concrete and the destroyed soil mantle can permanently retard the absorption and normal infiltration of precipitation. Accelerated runoff, both in volume and rate, is the consequence of this changed land condition, leading to the continuation of negative impacts on groundwater and receiving waterways.

Stormwater NPDES permits are generally not required for unconventional gas well pads. Only flowback from the well is regulated by the NPDES program.[iii] Due to inadequate regulation of stormwater from well sites, including the current practice by DRBC to use host state stormwater regulations to manage stormwater, polluted runoff, erosion and sediment loading to adjacent waterways from well sites causes several negative stream impacts. These include 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. In turn, aquatic and riparian habitats and the flora and fauna species that rely on them are negatively impacted. Overall, the land is transformed from its current condition to an industrial site.

In a peer reviewed journal paper that examines the footprint of Marcellus shale gas and wind through scenario analysis, upwards of 1 ¼ million acres of new impervious surface can be expected across the Marcellus 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.[iv] The report points out that much of the land is now forested (about 70% of the entire

Marcellus Shale play), that forests provide important water quality benefits and the loss of forested land increases the cost of providing safe drinking water to the urban areas that rely on it.[v] This is of particular importance to the downstream developed areas in the Delaware River Watershed and in communities outside of the Basin that use the Delaware River for drinking water.

The economic hardship caused by diminished water quality and supply must be considered in assessing the potential impacts of fracking. In the Delaware River Watershed, water supplies contribute 3.82 billion dollars in annual value to the regional economy and water quality brings $2.5M in annual economic benefit to the Basin, according to a study out of the University of Delaware.[vi] When water is depleted, it has real economic impacts for the source watershed that has lost the value of that water and can force externalized costs on to the consumer.

A study that examined the location and footprint of gas well sites found substantial land clearing and forest fragmentation in Pennsylvania's Marcellus Shale regions and reported on impacts to fauna and flora. "In a study of 242 drilling pads on the Marcellus Shale in Pennsylvania, half were located in forested areas and an average of 8.8 acres of forest was cleared for each drilling pad with its roads and other infrastructure."[vii] "Assuming an ecological edge effect of 330 feet extending into intact forest from cleared areas, each drilling installation affected 30 acres of forest. Black-throated blue warblers, scarlet tanagers, ovenbirds, and other forest songbirds are adversely affected by fragmented forests because they avoid open areas."[viii] The openings in the forest canopy also increase exposure to predation and nest parasitism for these species. Other organisms that can be negatively affected by forest fragmentation include woodland pool-breeding amphibians, forest floor wildflowers with ant-dispersed seeds, and plants whose pollinators or herbivores are affected."[ix]

The amount of acreage disturbed is now trending upwards in size due to supersized wells with longer well bores. Mega-sized well pads are the trend, starting in 2016 and becoming more common in 2017. Therefore, the impacts will be greater as the disturbance and actively used areas of a well site expands. This is discussed in more detail in this Comment on page 24.

The documented benefits of forest ecosystem services to water purification are discussed in a U.S. Forest Service report; the loss of these services can degrade water quality.[x] 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.[xi] Approximately 85% of the lands underlain by Marcellus Shale in the Delaware River Basin is forested. (Schmid) Approximately 85% of the Appalachian Basin in the Delaware River Watershed is forested.[xii]

Researchers at the Academy of Natural Sciences have discovered that where high density of natural gas wells occur, adjacent streams in Pennsylvania's Marcellus are experiencing decreased water quality as demonstrated by lower macroinvertebrate density and higher levels of specific conductivity and total dissolved solids.[xiii] A publication of the

Proceedings of the National Academy of Sciences found streams adjacent to gas wells are negatively impacted by runoff and sedimentation (Total Suspended Solids), harming benthic life, fish and wildlife and causing streams to be eroded and destabilized.[xiv]

According to a peer reviewed paper assessing stream vulnerability to unconventional oil and gas development, approximately 79% of assessed U.S. river and stream miles have degraded environmental conditions with significantly altered biological communities.[xv] Common stream stressors that degrade water quality are excess nitrogen and phosphorous, metals, sediment, and other contaminants from agriculture, urbanization, and wastewater.[xvi] Development for energy sources such as mining has had large impacts on stream quality over the years. Today, unconventional oil and gas extraction (UOG) from shale has the potential to alter streams through land development, spills, water withdrawals, and wastewater production.[xvii] The report states that adding these impacts to the existing stressors will have an unknown level of impact. The study developed indices to describe watershed sensitivity and exposure to disturbances and compared various shale plays. Catchments in the Barnett and Marcellus-Utica were naturally sensitive from more erosive soils and steeper catchment slopes.[xviii] These catchments also encompassed areas with greater UOG densities and urbanization.[xix] These findings document that development of shale gas in the Delaware River Basin can be expected to have negative impacts due to the natural conditions of the watershed and that as intensity of development increases, so do the adverse impacts.

Wetlands are located throughout the portions of the Basin underlain by gas-bearing shales. Forested wetlands are characteristic of these regions. However, DRBC has not developed detailed maps of regulated wetlands in the Basin. (Schmid)

> "There are no detailed maps of regulated wetlands in the Basin. Existing National Wetland Inventory maps show the general location of wetlands recognizable from aerial photographs, but omit many forested wetlands, which are characteristic in the Special Protection watersheds of the Basin, and which offer special habitat values over and above other kinds of wetlands in this biome (Schmid& Co., Inc. 2014)."[xx]

Wetlands are sensitive to development activities and are documented to have been degraded by oil and gas development. There is substantial potential for destruction and loss of wetlands if fracking were to occur in the Basin. (Schmid)

> "Wetlands are among the most threatened ecosystems on the planet. They are degraded and converted to human uses more rapidly than any other ecosystem, and the status of freshwater species is deteriorating faster than any other species. Since wetlands are essentially characterized by hydrologic conditions, changes in water volumes and timing of flows are major threats, as are discharges of various pollutants."[xxi]

A report on frack well sites documents the harmful impacts to wetlands and wetland species. "Brackish (salty) wastewater released at a wellsite can pollute streams and wetlands, rendering them unsuitable for many salt-sensitive freshwater organisms including frogs, salamanders, fishes, and many freshwater plants."[xxii] Plants are also adversely affected. "Brackish wastewater spilled or leaked onto soil would render the habitat unsuitable for many common and rare woodland plants including some trees, as well as many soil invertebrates."[xxiii]

A report from New Jersey Department of Environmental Protection concludes that less than half the wetlands mitigated over time were successful; only 48% concurred with their design specifications on average, leaving most sites without the mitigation goals accomplished.[xxiv] A report from the New Hampshire Office of Energy and Planning warns that there is a lack of scientific evidence that documents the success or failure of mitigating adverse impacts through wetlands creation or expansion; contracted wetlands are not necessarily successfully providing environmental benefit.[xxv] In other words, mitigation is a leap of faith not founded on scientific evidence.

The U.S. Council on Environmental Quality states that impacts should be avoided altogether by not taking a certain action or parts of a certain action and includes as options to minimize, reduce, rectify and compensate for adverse impacts of development.[xxvi] 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.

Examining the trend in shale gas development today, the size of well pads is expanding as horizontal well bores extend further (up to 4 miles in Pennsylvania's Marcellus Shale) and the geometry of drilling adjusts to allow more horizontal well bores to each vertical bore.[xxvii] Supersized well pads or "mega-pads" are the trend, starting in 2016 and becoming more common in 2017. DRBC's Supplementary Information states that the average total disturbance for a single well pad is 7.7 acres including access roads and gathering lines.

This estimated area to be disturbed for a fracking well site is now out of date. Companies such as EQT – the largest natural gas producer in the nation with offices in Pittsburgh - Range Resources and industry investor reports are touting the new "supersize" wells as the wave of the future, maximizing the investment of up to a half billion dollars on well pads with up to 20 wells. Some pads in the southwestern Pennsylvania area have up to 37 wells permitted.[xxviii] In the Permian Basin in Texas, one pad has 64 wells.[xxix]

The size of the well pad today is trending to be at least 10 acres in the Marcellus and Utica shale regions for these supersize wells, without considering the associated disturbances for access, pipelines, water basins, and other industrial activities required for well development. This translates into more impervious surface, more runoff, and more intense use of each site. It also means that industrial scale operations to develop the wells on a mega-pad will last longer, at least 3 years rather than the previously typical one year time frame.[xxx]

This means prolonged impacts on land and streams while wells are being constructed. This also provides more time for pollution events, spills, leaks and stormwater impact to occur, exposing the environment, waterways and the public to more risk for longer periods of time. And it prolongs the period of time that humans and wildlife are impacted by local air, noise, and light pollution, traffic impacts and other disturbances. For instance, the number of truck trips to transport water into a frack well site and to transport the waste out of the property also increases; typically 1400 truck trips are required to deliver the average 4.5 million gallons of water to frack a well. However, since water use has now more than doubled, the local truck traffic and the air emissions that are released by the diesel trucks can also be expected to increase by at least double.

Fracking Fluids, Injection, and Gas Production Impacts

The next phase of gas development involves the storage, handling, and use of chemicals and additives for extraction and stimulation of gas, the drilling and fracking of the gas well, and the release of gas from the geologic formation. The impacts of the production of flowback and produced fluids will be addressed in this comment under Section 440.5.

The two primary pathways for pollution to reach waters of the Basin from fracking and drilling operations are across the ground surface and through groundwater. (Tom Myers, "Technical Memorandum: Review of Proposed Natural Gas Regulations as Proposed by the Delaware River Basin Commission", March 12, 2018)

> "There are two primary pathways for contaminants to reach waters of the Delaware River Basin –across the ground surface and through groundwater. The primary source of contaminants on the ground surface is spills from operations or transportation."[xxxi]

Spills or leaks

The potential for contamination of ground and surface water from spills at a gas 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 wells. (Myers) Examination of data from four states, including Pennsylvania, found the occurrence of one spill per every 3.2 wells. (Myers)

> "Contamination can reach surface water near a gas well by flowing across the ground surface through small drainages to streams downhill from the source. The potential for spills or leaks to follow such a path is clear, but there is little specific research. Lefebvre (2017) found that spills or other surface releases represent the most probable mechanism leading to groundwater contamination. Most research concerning spills of fluids associated with O&G development focuses on well pad spills. For example, EPA's review of fracking-related spills was limited to spills near the pad (EPA 2015). In a substantial review paper concerning the impact of shale gas on regional water quality (Vidic et al. 2013), the authors cited just one report from grey literature (Considine et al. 2012) regarding spills and one journal article from the early 1980s regarding spills transporting through shallow groundwater (Harrison 1983). A more recent article (Maloney et al 2017) summarized details of the threats of spills at the well site harming nearby streams.
>
> Considering O&G development in four states, Pennsylvania, Colorado, New Mexico, and North Dakota, Maloney et al (2017) reviewed data from 6622 spills that occurred for 21,300 unconventional wells, a ratio of one spill for every 3.2 wells."[xxxii]

Of the four states examined in Maloney et al (2017) Pennsylvania had the closest proximity of wells to streams. (Myers) This means a more rapid delivery of pollutants to surface water and more difficult management of pollution incidents. Over the four states, 5.3% of the reported spills in Pennsylvania were within 100 feet of a surface waterway. (Myers) Since Pennsylvania regulations only require a 100 foot separation from the edge of a well pad to a stream, compliance with those regulations will not prevent contamination from spills. These statistics show that to prevent gas well spills from causing pollution, prohibiting fracking is the best course.

> "The proximity to streams was smallest in Pennsylvania, with an average distance of 268 meters (Id.). This could be due to the higher density of streams in a humid-regions state like Pennsylvania as compared to the other states. Over the four states, 7% of spills were within 100 feet of a stream, and 5.3% of the spills in Pennsylvania were within this distance. Maloney et al (2017) reported that the required setback in Pennsylvania is 100 feet, so decisionmakers should not rely on compliance with regulations to protect streams. The statistics regarding spills shows that DRBC is correct to ban fracking within the DRB to protect streams within the basin."[xxxiii]

Groundwater contamination occurs when pollutants are spilled onto the ground surface and are infiltrated to shallow groundwater. This contamination can then easily be transported to surface water. (Myers) The likelihood of water contamination from fracking is great due to the vulnerable nature of the headwaters regions of the basin, supporting the prohibition of fracking as the most effective means of preventing the spread of contamination from spills. (Myers)

> "A groundwater flow pathway unique to headwaters regions within the DRB is shallow transport from spills or leaks of surface storage. The distance from any point on a

> drainage basin to a first-order stream is short, on the order of a few hundred to perhaps a thousand feet. Shallow aquifers especially on ridges are thin (Taylor 1984) and the water table follows the topography. Thus, spills would move as interflow from the source to streams relatively quickly, on the order of days."[xxxiv]

Spills or leaks at fracking well sites contain very dangerous chemicals and hazardous substances. For instance, hydrocarbons, petroleum distillates, and diesel range organic chemicals (DRO) have been found in soils and shallow groundwater near spill locations at well sites. (Myers) These are very difficult to clean up and remain 25 times longer in the clay-rich soils found in the Basin, making prevention rather than mitigation the preferred approach to water resource protection. (Myers) Radioactive materials are also more likely to be found at spill locations at fracking sites; radioactive properties are also extremely long-lived (the half-life of radium 226 is 1600 years).

> "Spills of fracking fluids include hydrocarbons and petroleum distillates which linger in the soils and are difficult to clean up (Maloney et al 2017), regardless of whether the spill is at the pad or during transportation. Ripendra (2016) found contamination by wastewater disposal and accidental leaks and spills of wastewater and chemicals used during drilling and the hydraulic fracturing process to be two of the four primary threats to water quality posed by fracking, with the other two being well integrity related.
>
> Drollette et al (2015) found in the Marcellus region an elevated concentration of diesel range organic chemicals linked to hydraulic fracturing fluid within shallow

> groundwater. They associated it with spills, primarily at the well sites, by correlating DRO concentration with distance from wells. They did not test for distance from other types of spills, presumably because the location of those spills is not available in the data base. In addition to showing potential for long-term contamination near well sites, these results suggest there would be long term DRO contamination near all spill sites. The contamination from spills into clay-rich soils is likely to linger as much as 25 times longer than for gravely soils (Cai and Li 2017). The contamination is also likely to contain higher concentrations of various radioactive substance (Lauer and Vengosh 2016)."[xxxv]

Complicating the problem of spills at fracking sites is that much is not known. This is due to lack of routine monitoring that could catch unreported releases or the accumulation of smaller spills, inadequate reporting and enforcement systems, and the use of hazardous materials that are unidentified or are protected by trade secret laws. "Little information is available on the potential impacts of some fracking chemicals on streams, wetlands, or upland soils. Because some of these chemicals are known to be endocrine disruptors or carcinogens, these substances would undoubtedly cause harm to many stream, wetland, and forest wildlife species."[xxxvi]

<u>The Fracking Process</u>

Contamination of groundwater aquifers by fracking occurs underground and involves at least three different substances – natural gas, formation brine, and fracking 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. (Myers)

> "The most complex transport pathways for contaminants from fracking to reach Watershed lands occur underground, between the point of fracking and shallow groundwater or surface water. At least three different substances released by fracking can reach shallow groundwater or surface in the DRB – natural gas (shallow biogenic and deep thermogenic gas), formation brine, and fracking fluid. All would be part of produced water as defined by the proposed regulations if they transported up the well bore to shallow groundwater or surface water. These contaminants can follow pathways through natural faults and fractures, through abandoned wells or poorly constructed gas well, or a combination of both."[xxxvii]

Natural gas is a mixture of carbon-chain gases, with methane (CH_4) being the dominant. (Myers) There are many studies that have documented increased concentrations of thermogenic (from deep geologic formations) CH_4 within one kilometer of fracked wells. (Myers) Valley locations along faults have also collected CH_4 and fractures caused by faulting is considered to provide pathways to the surface. (Myers)

A peer reviewed study by Tom Myers explained several ways that shallow groundwater can become concentrated with CH_4 including: microbial methane production; natural migration over time; vibrations from drilling activities that drive natural gas towards shallow groundwater; leakage from target or intermediate-depth formations through a poorly cemented well annulus; leakage from target formations through faulty well casings;

migration of gas from deep formations along natural faults, joints, or fractures; migration of deep formation gas through faults or fractures caused by drilling or fracking; migration of deep or intermediate gas through abandoned or orphaned wells. Earthquakes may also cause vibrations that cause gas to be released and earthquakes may also be associated with increased fracking. Gas migration into groundwater can affect water wells. (Myers)

> "Darrah et al. (2014) listed the following scenarios that can lead to higher methane concentrations in shallow groundwater:
>
> > (i) in situ microbial methane production;
> >
> > (ii) natural in situ presence or tectonically driven migration over geological time of gas-rich brine from an underlying source formation or gas-bearing formation of intermediate depth (e.g., Lock Haven/Catskill Fm. Or Strawn Fm.);
> >
> > (iii) exsolution of hydrocarbon gas already present in shallow aquifers following scenario 1 or 2, driven by vibrations or water level fluctuations from drilling activities;
> >
> > (iv) leakage from the target or intermediate-depth formations through a poorly cemented well annulus;
> >
> > (v) leakage from the target formation through faulty well casings (e.g., poorly joined or corroded casings);
> >
> > (vi) migration of hydrocarbon gas from the target or overlying formations along natural deformation features (e.g., faults, joints, or fractures) or those initiated by

drilling (e.g., faults or fractures created, reopened, or intersected by drilling or hydraulic fracturing activities);

(vii) migration of target or intermediate-depth gases through abandoned or legacy wells"[xxxviii]

Also documented by studies using tracers during fracking, gas can move quickly from the well into the surrounding environment and can move between rock layers under the ground. (Myers) This means that the release of CH4 is difficult to control and can be difficult to mitigate.

"Gas tracers released during fracking were found at production wells 750 feet away from the source within days (Hammock et al 2014). They also found evidence of gas migration to a sandstone formation 3000 feet above the Marcellus shale (Id., Figure 33). A model study based on conditions found at the southwest Pennsylvania site used in Hammock et al. estimated that gas can flow from a well bore leak through a sandstone rock matrix to a well 170 m away in times ranging from 89 days to 17 years depending on conditions (Zhang et al 2014). Darrah et al. (2014) found several gas wells within one kilometer of fracked wells that experienced large increases in gas concentration between annual sampling events which suggests that gas transport of up to a kilometer occurred in a time period of less than a year.

Additional evidence of gas movement along faults through the earth's crust to shallow groundwater may be seen through studies concerning CO_2 sequestration. Shipton et al.

(2004) found that fluids (liquid and gas) can move vertically through low permeability faults, including those otherwise considered to be sealed with calcite."[xxxix]

The movement of gas through various faults and pathways is also extremely variable and hard to predict. (Myers) But the evidence of the ability of gas released by drilling and fracking from deep formations to reach shallow groundwater and water wells, springs and streams is scientifically affirmed. (Myers) The effects of CH4 concentrations in streams and on aquatic life can be devastating.

"It is common to ignore the presence of methane in streams. Methane degases from surface water, but without sufficient aeration, the methane decreases the dissolved oxygen in the surface water which would have severe aquatic effects. Essentially, methane discharges to streams increase the dissolved methane content of the stream thereby decreasing the dissolved oxygen content for areas near the methane source. This can lead to dead zones just as anything else that depletes oxygen."[xl]

The forces that cause the release are many and complex, are not usually understood or required to be analyzed prior to drilling and fracking a well and are not uncommon. To avoid CH4 contamination, prevention is the most effective approach.

Formation brine, under natural forces, moves from deep rock formations to shallow groundwater through natural faults and fractures. (Myers) Reports point out that these same pathways are available for fracking fluids to shallow groundwater. Studies have proven that fracking fluid has reached drinking water wells and that transport has occurred between the gases well and shallow groundwater. The flow of deep brine to the surface and between shale layers is well documented in scientific literature over the years. (Myers)

> "Formation brine naturally flows through faults and fractures from the Marcellus (Warner et al. 2012) or other deep Appalachian basins to shallow groundwater (Llewellyn 2014) based on geochemical and isotopic evidence. Both papers warn that these connections could allow more rapid brine flow or portend the flow of fracking fluid to shallow groundwater due to increased pressure or enhanced connections due to fracking. At least three published studies have documented fracking fluid reaching drinking water wells (Llewelyn et al 2015, DiGiulio et al. 2011; EPA 1987) and litigation settlements have prevented disclosure of the facts in similar circumstances. Llewelyn et al (2015) documented transport between a fault plane/well intersection 1600 feet BGS and a shallow aquifer.
>
> Model studies for years have simulated the potential for deep brine to circulate to the surface naturally (Deming and Nunn 1991; Person and Baumgartner 1995) or in conjunction with deep waste or CO2 injection (Birkholzer and Zhou 2009)). The role of fractures to allow flow through shale layers has also been known for years, with Bredehoeft et al. (1983) finding that at a field scale, the vertical conductivity of shale is up to three orders of magnitude greater than the conductivity estimated from a column in a laboratory."[xli]

Marcellus Shale has been modeled to show that deep brine and fracking fluids can be transported from the Marcellus to shallow aquifers over a period of ten years to more than a thousand years. (Myers) Numerous modeling studies show that these fluids can move from deep formations (where fracking occurs) to drinking water and surface waters. Two studies that countered these findings have serious flaws that have been exposed. (Myers)

> "Myers (2012) found that transport from the Marcellus to shallow aquifers could occur over a period from 10 to more than a thousand years, depending on the conductivity assumed to result from fracking -- his model had the horizontal gas well intersecting a vertical fault connecting the shale to the near-surface. Gassiat et al. (2013) modeled a high permeability, continuous, 10-m wide fault zone from the shale to the shallow groundwater with fracking simulated as a change in permeability over a 2-km long, 150-m thick zone. Kissinger et al. (2013) simulated a continuous 30-m thick vertical fault with a head drop of up to 60 m to drive a plume of fracking fluid into the lower aquifer. After 30 years under this scenario, simulated fracking fluid had reached the shallow aquifer. Lateral migration of contaminants occurred at rates up to 25 m/y (Lange et al. 2013). Chesnauw et al. (2013) modeled flow along a fracture pathway between a target shale zone and surface aquifer in a two-dimensional framework, 3000-m long by 3000-m deep and 1 m thick. The modeling studies utilized generic stratigraphic and topographic cross-sections with idealized formation properties due to a lack of specific aquifer data. Also, they considered flow through a fault, but likely underestimated the potential for preferential flow through small but highly permeable fractures even within a preferential flow zone. Taherdangkoo et al (2017) found that upward fluid migration to a shallow aquifer depended on the characteristics of the fault, but argued the

probability remained small; they did not consider out-of-formation fractures intersecting the fault or a natural upward gradient in the fault zone due to common basin topographic circulation (Deming and Nunn 1991). Wilson et al (2017) used model simulations to show that fracking fluid could reach shallow aquifers through fault zones from a target shale greater than 2000 meters bgs. Travel time was quicker for increased induced fracture extent (out of formation fractures), absence of deep high hydraulic conductivity strata, and low fault hydraulic conductivity. The authors found that high conductivity horizontal formations intersecting the fault and high conductivity faults allowed fluids to leak off thereby reducing the mass reaching shallow groundwater."[xlii]

Brine from the Marcellus Shale uses pathways that are opened or expanded by fracking, allowing the free water that is contained in fracture zones to travel upwards. The fact that brine dominated the flowback after the initial flowback carried the nearest fluids – the fracking fluids – up the well bore, proves that there is free water in the deep formations and it is agitated, released, and transported by fracking. (Myers) The highly contaminated properties of this brine, including TDS, various salts, hydrocarbons, heavy metals, and naturally occurring radioactive materials (NORM) poses tremendous threat to the quality of groundwater, drinking water wells, and surface water in the Delaware River Basin. (Myers)

"Fracking provides a pathway for Marcellus brine, the free water, to flow to the gas well, probably becoming dominant after the fracking fluid remaining most closely near the well goes back up the well as flowback.

Haluszczak et al (2012) showed that brine dominated the flowback, based on the rapid increase in concentrations of various constituents, including TDS, Cl, Br, Na, Ca, Sr, Ba, and Ra, in the flowback to levels several times that of seawater. Flowback was not fracking fluid that had dissolved rock minerals from the shale as claimed by Engelder et al. Kohl et al. (2014) used strontium isotope ratios found in flowback to isolate the source formation; the strontium signatures would not be as representative of the source formation if its presence was due only to high velocity dissolution during fracking. Rowan et al. (in press, abstract, emphasis added) conclude that the "δ18O values and relationships between Na, Cl, and Br, provide evidence that the water produced after compositional stabilization is **natural formation water**, whose salinity originated primarily from evaporatively concentrated paleoseawater"."[xliii]

Because this movement of contaminants cannot be controlled underground, there is effectively no way to avoid the contamination it causes. The only way to avoid this substantial risk of pollution is to prevent it by prohibiting fracking within the Watershed.

"The proposed regulations properly prohibit fracking within the Delaware watershed. This section has described how fracking has been shown to cause pollution or how it is likely to do so in the future, both through the actual process of fracking and from well bore leaks. The potential for contaminants to reach groundwater through these pathways is a good reason for banning the process within the watershed. DRBC is correct in doing so."[xliv]

Scientific reports examine the competence of the cement that is used to seal the gas well bores that access gas and the steel that is used to encase the produced gas in the well bore. One report investigated many industry and technical reports on these issues and provides ample evidence of the substandard well construction and plugging and abandonment regulations that are in place. 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. "Because hydraulic fracturing opens joints well beyond the borehole, plugging and abandonment practices may do little to protect the environment after chemical additives are repeatedly injected into bedrock formations under high pressure. Also, presently used cement mixtures and other materials do not achieve zonal isolation in each well, allowing for gas migration and the escape and comingling of fresh and contaminated subsurface waters."[xlv] The report concludes that the implications of short term cement failure on long term aquifer water quality protection are extremely significant. As stated in the report[xlvi]:

> "Aquifer protection requires the use of downhole methods and materials that, like aquifers, will stand the test of time and harsh physical conditions. Current state-of-the-art cement materials used in well completion and plugging and abandonment operations do not have a documented long-term history of durability. Cement mixtures or alternate sealant materials must be capable of maintaining the long-term hydrologic integrity of freshwater aquifers separate from deep underlying geologic formations that contain saline water enriched with natural gas, radioactive elements, and hydrofracture-related chemicals. Inherent in permitting and the regulation of gas wells is the concept that

groundwater quality will be maintained and will be available as a potable water source in perpetuity.

Freshwater aquifers have taken millions of years to form. As geologic layer after geologic layer was deposited, buried, and eventually lithified over time, many became physically isolated from overlying strata. Some of the deeper bedrock horizons contain old, brine-rich, connate waters that are present in the pores of the bedrock. This saline water was either trapped in bedrock pores when the rock units were formed or became highly saline later in time through mineralization due to stagnant flow conditions (Fetter, 1994). Under natural conditions, this pore water is not encompassed by the hydrologic cycle. Gas drilling activities provide a mechanism whereby deep formation waters now have an avenue to commingle with overlying freshwater aquifers if failure of zonal isolation materials occurs."

"The oil and gas industry has long recognized the need to maintain the long-term integrity of boreholes that breach bedrock formations that have naturally and effectively isolated freshwater aquifers from deep connate waters for millions of years. Research continues in efforts designed to lead to better practice and better cement formulations, including some self-sealing mixtures that are newly developed but have not been tested for years in the harsh downhole environment."

"Cement shrinkage, debonding, and failure can result from a variety of causes including too high a water content, water expulsion, shrinkage after setting and during hardening, radial cracking, tensile failure, compressional failure, traction, cement dehydration, osmotic dewatering in the presence of high salt content formation brines, corrosive gases, high formation pressures and temperatures, changes in temperature and pressure, sustained casing pressure (SCP), poor cement blends, pressure testing, gas and water channeling, gas migration through setting cement, influx via mud channels, internal and external microannulus development, cement shattering, and cement plastic deformation (e.g., Dusseault et al. 2000; Heathman and Beck 2006; Brufatto et al. 2003; Kellingray 2007; Lecolier et al. 2006; Newhall 2006; Mainguy et al. 2007; Teodoriu et al. 2010; Ladva et al. 2005; Moroni et al. 2007; Ravi et al. 2002; Gray et al. 2007; Reddy et al. 2007; Darbe et al. 2009; Bellabarba et al. 2008; Daneshy, 2005; Crook and Heathman 1998; Boukhelifa et al. 2005; Tahmourpour et al. 2008).

Problems with the integrity of well cement are well known in oil and gas fields. For example, twenty-five to thirty percent of wells in one shelf study area were estimated to have annular pressure problems (SCP) in five to six years, reaching 60 percent in 27 years (Kellingray 2007). Fractured shales of the Appalachian Basin may present problems when cementing wells (Newhall 2006)."

"Assorted researchers are evaluating the service-life of reinforced concrete structures susceptible to chloride corrosion (e.g., Trejo and Pillai 2003). Similarly, Shiu (2011), of Walker Restoration Consultants, states that reinforced concrete structures generally have a service life of 30 to 40 years. Their work may help assess the maximum potential service life of concrete under various conditions. Research to date indicates that the life of concrete in both above ground and downhole conditions, under the best of circumstances, may be less than 100 years. Even if this preliminary assessment is in error by an order of magnitude and the life of concrete is 1,000 years, this time frame for the design life of concrete very quickly results in jeopardizing the useful life of Delaware River Basin aquifers in far less than 1,000,000 years – in only 0.1 percent of the conservatively estimated life of aquifers." [xlvii]

Considering groundwater flow, time, and the corrosive downhole environment created by gas extraction processes, including the lack of durability of the cement sealant and steel well casings, aquifers and surface waters are not sufficiently isolated from the gas, toxic fluids and deep geology pollutants that are distributed by drilling and fracking.[xlviii] Aquifers could be impacted quickly, such as when there is a faulty cement seal or casing during construction, or over time. But it is certain that the life of the cement and/or steel (up to 100 years under good conditions) is less than the life of the aquifer - so even if there is no evidence in the near term, the eventual pollution is likely occur in less than a century.[xlix] It is not a matter of "if" these wells will fail, but a matter of "when".[l] And when that does occur, water sources are ruined for the generations to come. This is not an acceptable legacy for DRBC and this unavoidable problem supports a ban on fracking.

Fracking is responsible for a plethora of environmental and public health problems where it is occurring, including in the Marcellus and Utica Shales in Pennsylvania. The harms are documented in a growing body of scientific literature and in data being produced by agencies and reporting mechanisms such as FracTracker (https://www.fractracker.org/map/us/pennsylvania/) SkyTruth (https://www.skytruth.org/) and industry sites such as FracFocus.

SkyTruth uses technology to identify and monitor threats to the natural environment.[li] As part of that work, SkyTruth collects violations of permits for oil and gas development for subscribers. Attached as **Attachment 3** is an excel document that contains all the violation SkyTruth collected from PADEP's website (http://www.dep.pa.gov/Pages/default.aspx) since May 2012, a total of 2765 reported violations. These may not include all of the violations since the information varies depending on time of inspection and issuance of violation, follow-up actions, and other details, according to SkyTruth staff.[lii]

Arguably the most comprehensive collection of scientific literature on fracking and its impacts is the Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking, 5th Edition.[liii] The Fifth Edition of this authoritative report started in 2014 examining the impacts of fracking on the environment and public health was published March 13. DRN has submitted the entire Compendium through the DRBC's web portal as comment on the Draft Regulations in a separate submission from this Comment.

The health professionals who reported and analyzed over 1,200 peer reviewed research articles for the Compendium concluded in the report: The "…findings to date from scientific, medical, and journalistic investigations combine to demonstrate that fracking poses significant threats to air, water, health, public safety, climate stability, seismic stability, community cohesion, and long-term economic vitality. Emerging data from a rapidly expanding body of evidence continue to reveal a plethora of recurring problems and harms that cannot be sufficiently averted through regulatory frameworks. There is no evidence that fracking can operate without threatening public health directly or without imperiling climate stability upon which public health depends."[liv]

Another related report is a literature review that examines literature compiled on fracking impacts for an earlier edition of the Compendium. The report concludes that the body of scientific evidence demonstrating the negative environmental and human health effects from unconventional natural gas development (UNGD) is very strong. The authors of a 2016 study evaluated peer-reviewed literature published between January 1, 2009 and December 31, 2015 as they related to the potential impacts of UNGD on public health, water quality, and air quality. The boundaries of the assessment included scientific literature on hydraulic fracturing and the associated operations and ancillary infrastructure required to develop and distribute unconventional natural gas.[lv] The results indicated that at least 685 papers have been published in peer-reviewed scientific journals that are relevant to assessing the impacts of UNGD.[lvi]

A portion of these papers covering each category (public health, water quality, and air quality) was selected by the authors to review. Of the 31 studies selected for public health, 26 (84%) contained findings that indicate public health hazards, elevated risks, or adverse public health outcomes from UNGD.[lvii] Of the 58 studies related to water quality, 40 (69%) had findings that indicated potential, positive association, or actual incidence of water contamination from UNGD.[lviii] Finally, of the 46 studies associated with air quality, 40

(87%) had findings that indicated that UNGD increased air pollutant emissions and/or atmospheric concentrations.[lix] This study demonstrates that the weight of the findings in the scientific community indicates hazards and elevated risks to human health as well as possible adverse health outcomes associated with UNGD.

Another important source of data about the impacts of gas development is the website of the Pennsylvania Department of Environmental Protection (PADEP). PADEP has determined that there are 307 cases of private water well contamination caused by oil and gas operations in the Commonwealth, as of 3.23.18.[lx] This number does not include ongoing investigations or cases that were settled and are now subject to a non-disclosure agreement. The number also represents "cases", as many as 16 water wells and, in the case of Dimock, PA, nine square miles of aquifer were contaminated but the contamination was counted as one "case". There are also cases that were not found to meet PADEP's requirements to be determined as definitely caused by oil and gas operations that are still unresolved by well owners. It is important to also recognize that PADEP uses data collected pursuant to oil and gas regulations which have limited zones of influence around the gas well that can be considered, limited periods of time in which contamination can be considered, and a limited number of contaminants for which sampling is done. For instance, methane migration into water wells caused by fracking is not being counted by PADEP as a pollution incident[lxi] and yet it can render a water well unusable and has health and safety impacts for the residents.

For instance, if contamination occurs after the period of time that a water well in proximity to a gas well is required to be monitored, the contamination may not be considered as legitimate. Further, because the sampling of water wells within the zone of presumption is compared to current background water quality, pollution events can be masked by prior contamination of an aquifer, leaving the well owner without the proof needed to receive a positive letter of determination from PADEP. It also means that because background concentrations are used as the standard to which groundwater must be cleaned under Pennsylvania's Act 2, aquifers where fracking contamination has occurred but had not been discovered will be condemned to a downward spiral of water quality as the "new normal" becomes the contaminated condition.

Therefore, the 307 cases – in itself representing an unacceptable loss of residents' well water quality and clean drinking water - that have been "positively determined" by PADEP are more than likely an under-representation of the total number of private water wells that have been contaminated by oil and gas operations in Pennsylvania. Since the number of "positive determinations" continues to rise as new cases are resolved, it is clear that private water wells and the aquifers of Pennsylvania are not protected from degradation by gas and oil development and fracking, regardless of the adopted regulations.

The Delaware River Basin would be exposed to this same risk. Over 4,400 water complaints related to oil and gas have been filed by the public with PADEP. Between 2004 and 11.2016, PADEP lists a total of 9,443 public complaints about environmental problems in shale gas drilling areas.[lxii] As fracking has progressed in Pennsylvania, instead of practices improving and the adoption of new regulations by PADEP reducing gas and oil operation-related complaints, the ratio of complaints has increased.[lxiii]

Finally, the U.S. Environmental Protection Agency's (EPA) Hydraulic Fracturing study issued in 2016 after seven years of research provides scientific evidence that fracking activities can impact and have impacted drinking water resources.[lxiv] EPA also has published an analysis of oil and gas industry spills.[lxv] The false claim that fracking has not contaminated water supplies cannot be made with a straight face; EPA and other reports (see "Compendium" and other references in these comments) have proven it has and that water pollution incidents can be expected to continue.

It is also important to recognize the shortcomings of some analyses, especially if the results are being mischaracterized. Some members of the public have been describing a report issued by the Susquehanna River Basin Commission (SRBC) as concluding that there are no adverse impacts from fracking to the water resources of the Susquehanna River Basin. In fact, the U.S. Geologic Survey and Northeast-Midwest Institute conducted a review of the SRBC report and concluded that the existing water quality data in the Susquehanna River Basin are inadequate to assess whether the increase of shale gas development activity in the Susquehanna River Basin is causing adverse changes in water quality.

The report states that the rapid growth of high-volume hydraulic fracturing (HVHF) in the Susquehanna River Basin has raised concerns about the potential for degraded surface-water quality and potential impacts on drinking water aquifers throughout the basin. USGS and the Northeast-Midwest Institute outlined the key elements necessary to assess the impacts of shale gas development in the Susquehanna Basin. First, it is necessary to collect sufficient water-quality monitoring data. The cumulative effects of shale gas development are more subtle to detect and water-quality monitoring is the only path to identifying low level and long-term changes. Without water-quality data, the long-term cumulative effects of shale gas development on water quality will be unknown.[lxvi] The report concludes that existing surface-water quality data in the Susquehanna River Basin are insufficient to detect water-quality change related to shale gas development.[lxvii] The key steps to generating the needed data include increased monitoring at a subset of priority monitoring sites that includes increased sampling frequency, sampling for additional priority parameters and streamflow, and commitment to long-term monitoring.[lxviii]

The report explains that surface water monitoring sites should be located in each of the four ecoregions with active or planned shale gas development, because stream chemistry in each ecoregion is unique and will respond differently to disturbances or changes in land use.[lxix] Monitoring sites must be located in watersheds with fracking wells and in reference watersheds in each ecoregion (areas with no fracking well development). Monitoring sites in both types of watersheds allow for the detection of water-quality changes that can be compared to identify whether these changes are resulting from natural gas development.

The report states that water-quality and streamflow data at these monitoring sites must be available with sufficient sampling frequency and duration to evaluate trends in concentration over time.[lxx] It also states that data on shale gas development, geology, climate, and other changes in land use throughout the monitored watershed must be available to correlate water-quality change with shale gas development activity. Without this information, the relationship between shale gas development and water quality cannot be evaluated.[lxxi]

The report further states that networks of groundwater sampling sites are also needed with each sampling site located within 1 mile of a fracking well. Water quality data collected before and after shale gas development are necessary in order to detect groundwater quality change. Information on the shale gas development, geology, other changes in land use, and climate near those sampling sites must be available to compare water-quality change with shale gas development activity.[lxxii] Next, a suite of water quality parameters is needed to determine if contamination from the cumulative impact of shale gas development activities has occurred in the Susquehanna River Basin. The suites of priority parameters for surface water and groundwater should be based on the specific hydrology, geology, past and current land use, and other environmental concerns expressed in the Susquehanna River Basin.[lxxiii]

The report says that monthly sampling frequency is needed to detect changes in water quality year-round and to minimize the time needed to detect statistically significant water-quality change at each monitoring site. A minimum of eight surface-water monitoring sites are needed: one monitoring site in a watershed with fracking wells and one reference watershed monitoring site is needed in each of the four ecoregions with active or predicted shale gas development.[lxxiv]

According to the report, the magnitude of water quality change that could occur from contamination related to shale gas development is unknown, but it would take 3-6 years of monthly monitoring to detect a 20% change in median specific conductance or total barium in the Susquehanna River Basin.[lxxv] Only 4 of 22 surface-water monitoring sites in the Susquehanna River Basin with enough existing data for a water-quality trend analysis for barium or specific conductance are located in watersheds with active fracking wells, and few of the 26 recommended surface-water monitoring parameters are available for those sites.[1lxxvi] Only one of those monitoring sites is in a watershed with a fracking well density greater than 0.5 wells per square mile.[lxxvii] The existing surface-water data in the Susquehanna data set are not sufficient to detect whether the cumulative effects of shale gas development are resulting in water-quality change.[lxxviii]

The report states that there is no systematic, large-scale, long-term monitoring effort underway to assess the effects of shale gas development on groundwater quality in the Susquehanna River Basin. The groundwater sampling sites with existing data are rarely located within 1 mile of a fracking well, but even when they are in the right locations the sites lack data for most of the priority groundwater parameters.[lxxix] In addition, the available groundwater data lack the sampling frequency needed for a water-quality trend analysis and lack the number and location of sampling sites needed for a spatial water-quality network analysis.[lxxx] Targeted, robust monitoring networks for both surface water and groundwater are critical for identifying whether the increase of shale gas development activity in the Susquehanna River Basin is causing adverse changes in water quality. The report thus concludes that the existing water quality data in the Susquehanna River Basin are inadequate to serve this purpose.

The findings of the USGS/Northeast-Midwest Institute analysis of the SRBC report were also reported in the USEPA's 2016 Hydraulic Fracturing Study.[lxxxi]

Air Pollution and Greenhouse Gas Emissions from Fracking

In the both development and production phases, natural gas has significant negative air quality and greenhouse gas impacts. While DRBC is responsible for protecting the water resources of the basin, it is known that air emissions effect water and ecological systems. When contaminants disperse to the air they eventually settle downwards, affecting water, soil, vegetation, species, and surfaces. The impact can be substantial, depending on the concentrations and dispersal pattern of the pollution. Many factors influence the effects of air emissions, including weather, climate, atmosphere and anthropomorphic influences.

Scientific reports have confirmed that air quality is impacted by natural gas operations. Air monitoring is not uniform or required in most instances, leaving large data gaps. However, studies have been done of air near gas activities and unhealthy conditions and increases in related illnesses have been discovered.

For example, Colborn et al. conducted an exploratory study in western Colorado where residences are in close proximity to natural gas wells and development.[lxxxii] The study was designed to explore the presence of volatile organic compounds (VOCs), many of which are associated with the production of natural gas, in this rural natural gas production area for one year. The sampling period spanned the timeframe before, during, and after development of a natural gas well pad. Development included drilling, hydraulic fracturing, and production operations. Baseline and weekly air samples were collected between July, 2010, and October, 2011, from a fixed sampling station near a well pad on which 16 vertical (directional) gas wells had been drilled, hydraulically fractured, and put into production during the course of the study.[lxxxiii]

Among the VOCs, four chemicals were detected in every sample: ethane, methane, toluene, and propane. Chemicals with the highest mean values across the sampling period were, in order of mean value: methane, methylene chloride, ethane, methanol, ethanol, acetone, and propane.[lxxxiv] Regarding the carbonyls, acetaldehyde and formaldehyde were detected in every sample. The highest values were for formaldehyde and crotonaldehyde.[lxxxv] Naphthalene was the only polycyclic aromatic hydrocarbon (PAH) detected in every sample and it was also found at the highest concentration among the PAHs detected.[lxxxvi] The most chemical detections occurred during the first four months of drilling, at a time when only one fracturing event occurred. Notably, the highest percentage of detections occurred during the initial drilling phase, prior to hydraulic fracturing on the well pad, and did not increase during hydraulic fracturing.[lxxxvii]

The study found that methylene chloride, a toxic solvent not reported in products used in drilling or hydraulic fracturing, was detected 73% of the time.[lxxxviii] This also stood out due to the extremely high concentrations in some of the samples, including one reading of 1730 ppbv, and three other readings more than 563 ppbv during the period of well development. In contrast, after activity on the pad came to an end and the wells went into production, the highest level of methylene chloride detected was 10.6 ppb.[lxxxix] Residents and gas field workers have reported that methylene chloride is stored on well pads for cleaning purposes.[xc] A literature search of the health effects of non-methane hydrocarbons revealed that many had multiple health effects, including 30 that affect the endocrine system, which is susceptible to chemical impacts at very low concentrations, significantly less than government safety standards.[xci]

The study also found that selected PAHs were at concentrations greater than those at which prenatally exposed children in urban studies had lower developmental and IQ scores.[xcii] While natural gas development and production continues to spread across the land it is moving closer to schools, homes, and places of business. The authors warned that at the same time more and more raw gas will be released into the atmosphere on a steady, daily basis. The report recommended that in order to determine how to reduce human exposure for both those who work on the well pads and those living nearby, systematic air quality monitoring of natural gas operations must become a regular part of permitting requirements.

This report covers many of the air impacts that accompany gas development and fracking. It shows that the various stages of drilling and fracking have impacts, that there are many toxic contaminants that are released by the drilling and fracking process and that many of them have significant adverse health effects upon exposure. The information contained in this report supports a complete prohibition of fracking and drilling and a prohibition of related activities. There are many other scientific reports and articles that are included in the "Compendium", submitted by DRN to the public record for DRBC's comment period on the Draft Regulations and discussed earlier in this Comment. Also, reports from the Southwest Pennsylvania Environmental Health Project[xciii] document air emission-related health problems in the vicinity of shale gas operations and facilities. Some of the data and reports from that Project are included in the Compendium.

In addition to problems associated with harmful air emissions from fracking and gas operations, odors are also a problem related to the storage, management, and treatment of fracturing fluids and in flowback produced by fracking. Odors are not just a nuisance, they can be a serious human health issue and can greatly affect the quality of life near a well site. Hydrogen sulfide is an example of an odorous gas that is nauseating (the "rotten egg smell") and is highly toxic. (Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018) It can cause illness and even death. There are other toxic odors as well released by fracking operations. (Miller)

> "Odors are a particular problem for management/storage/treatment of HF waters, and a variety of chemicals are present in hydrocarbon formations that can present a serious odor problem, which can be both a serious human health issue and can affect the quality of life of persons living near these sites. A very common, but toxic, constituent is hydrogen sulfide, characterized by a rotten egg smell. Other organic sulfides can also be present, including a variety of alkyl sulfides. Odors are very difficult to regulate, due to the vagaries associated with odor detection, acclimation, and differential effects on different persons. The severity of an odor is in the nose of the beholder. Odors are particularly bothersome to persons living downwind, and storage of HF waters in the Basin can very likely lead to complaints, which should be taken seriously."[xciv]

Radon is another dangerous gas that can be released in toxic amounts by fracking, due to the radioactivity of Marcellus Shale.[xcv] Radon is a radioactive decay product of radium and is a known carcinogen.[xcvi] Dr. Marvin Resnikoff states, “We support section 440.3 which prohibits fracking within the Delaware River basin. This is important, not only for the potential release of drilling fluids and contaminated water into aquifers but also for minimizing the potential release of the radioactive inert gas radon”.[xcvii]

According to a report that examined the potential impacts from fracking on the Delaware River Watershed, the development of shale gas wells could as much as double nitrogen oxides (NOx) emissions, compared to current air conditions in the Marcellus Shale counties of the basin.[xcviii] The release of the NOx is not expected to be short term, during fracking or construction like some of the air pollution associated with fracking operations.[xcix] But the gathering lines require compressor stations to move the gas from the well to market pipelines and those compressor stations are permanent necessity as long as the gas well is producing. So the air quality degradation and unhealthy condition created by the NOx is long-lived and unavoidable throughout the life of the producing gas well.[c] NOx and VOCs are precursors to ozone, or smog, which is known to cause respiratory illness.[ci] Other air pollutants are released by fracking and during all stages of gas development, including sulfur oxides, particulate matter, and volatile organic compounds such as formaldehyde, benzene, toluene, ethylbenzene, and xylene.[cii]

In the same study that examined the potential impacts from fracking on the Delaware River Watershed, health impacts from air emissions and other pollution from fracking was examined.[ciii] The report mapped the likely location of well pads in the Delaware River Watershed's Marcellus Shale region and estimated that 45,000 people live within 1 mile of a projected well pad, virtually the entire population of the location where fracking is most likely to occur.[civ] The study reported that scientific literature documents that some health risk factors are related to the distance from a well pad to a person's home.[cv] 60% of the health of Wayne County's population could be affected by close proximity to a well pad.[cvi] The study examined the pollutants that people would be exposed to, based on scientific studies (CNA, Table 12).[cvii] These findings make very clear that the effects of gas development and fracking on the air and the health of the people of the region are inescapable due to the proximity of projected well pad locations to the population. It is unacceptable to sacrifice the air quality and health of the people of the Marcellus Shale region in the Delaware River Basin so that shale gas can be developed. The only protective option is to prohibit fracking and gas development completely.

Methane pollution and greenhouse gas releases from natural gas development significantly contribute to air degradation from natural gas, whether during stimulation and production or during transport when pipeline leakage is a mounting problem. Methane is an ozone precursor.[cviii]

Natural gas is primarily methane, a greenhouse gas 86 times more efficient at warming the atmosphere than carbon over a 20 year time frame[cix] and its effects persist for hundreds of years[cx]. The well documented vented and fugitive losses from natural gas systems contribute to atmospheric warming; current technology and practices have not controlled these releases. The emissions from shale gas development are so great that it is projected that their release from the build out of Pennsylvania's Marcellus shale will prevent the achievement of global warming goals in the state, accelerating climate change.[cxi]

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 salt water intrusion to Delaware River Estuary water supplies, the drinking water source for millions of people) and sea level rise[cxii].

Again looking at the study referenced above that examined the potential impacts from fracking on the Delaware River Watershed, the amount of leakage from natural gas development in the Watershed was estimated to be approximately at least an additional 0.5 to 2.2% per year, which would be added to the current releases from the Marcellus Shale play in Pennsylvania and West Virginia.[cxiii] Considering the potency of methane as a greenhouse gas, this burden adds to the growing problem of atmospheric warming from methane, fueling the advance of climate change for the planet. This is an adverse impact of fracking should be considered by DRBC because of the environmental and water-related problems that are caused by climate change and global warming, as discussed above.

The adverse water resource and health impacts caused by methane being released to the atmosphere are another of the impacts of fracking that cannot be eliminated; the leaked and vented gas is part of the fracking process and, even with attempts to develop performance standards to reduce or control leaks and venting, the effort has been ineffectual. As stated in a review of the Center for Sustainable Shale Development Standards, Dr. Robert

Howarth rejects what was touted as a new "gold standard" from industry practices that could reduce methane emissions substantially as full of loopholes and too vague to be effective.[cxiv]

In fact, the sources of methane emissions from components that make up fracking operations in the Marcellus Shale region are largely unavoidable, extremely difficult and/or expensive to control in terms of methane emissions, including: gathering lines; compressors for gathering lines; the use of under-balanced drilling and the presence of "faults" such as those found where mining has occurred (such as would be found in the anthracite coal mining areas of the western portion of the Delaware River Upper Basin); and the venting of gas, including "non-pipeline quality" or "low flammability" gas, venting during completion of a well, venting from exploratory wells that are not equipped to flare and on-site "de minimis" venting.[cxv]

Methane is a very difficult gas to control and it is so potent that its effects are outpacing the global effort to control the warming of the earth's atmosphere. Studies are showing that methane emissions are rising, even as carbon emissions are just beginning to slow. As stated is a news article about a new study that reveals the huge negative impacts of methane: "What's true for carbon dioxide is not at all true for methane, the second most important greenhouse gas. Atmospheric concentrations of this gas — which causes much sharper short-term warming, but whose effects fade far more quickly than carbon dioxide — are spiking, a team of scientists reports in an analysis published Sunday in the journal Environmental Research Letters."[cxvi]

As Dr. Robert Howarth of Cornell University eloquently explains, “We need to reduce carbon dioxide. We’ve already put 90% of the carbon dioxide we can into the atmosphere and keep the earth well below 2 degrees Celsius, so we can’t afford to put much more carbon dioxide up there. But no matter what we do for carbon dioxide over the coming years and decades, the planet will continue to warm to 1.5 degrees [Celsius] in 12 years and to 2 degrees [Celsius] in 35 years unless we cut methane emissions. The planet responds much much faster to methane than to carbon dioxide. There was a lot of talk at COP21 that yes, we need to start looking at these short-lived climate pollutants. We need to focus attention on them. We need to do it internationally within the next 2 or 3 years. So, we need to cut methane. Where is methane coming from? The major source in the United States is the natural gas industry. There’s no question about that. And there’s good evidence that shale gas development has accelerated that and perhaps doubled the methane emissions for the natural gas industry because of that. So this completely undercuts the idea that natural gas is a bridge fuel. It cannot be a bridge fuel for it to meet the COP21 targets.”[cxvii] The fact is, methane is a major part of the global warming problem and it is essential that action be taken wherever possible to prevent its release.

Methane emissions are so large they can now be seen from outer space.[cxviii] These findings support the prevention of methane releases to the atmosphere by the complete prohibition of fracking in the Delaware River Watershed.

<u>Comments in opposition to the export of water and water resources out of the basin for fracking at Section 440.4</u>

DRN opposes the Draft Regulations at Section 440.4 that would allow the diversion, transfer or exportation of surface water, groundwater, treated wastewater or mine drainage water from the Delaware River Basin to support fracking outside the basin. DRN requests that this Section 440.4 as written be removed from the draft regulations. Despite a statement by the DRBC that this practice is "discouraged", the regulations lay a road map for drilling companies showing how to successfully receive DRBC approval. Due to trends in industrial practices over recent years and the proximity of high-producing gas wells in adjacent Susquehanna County and other portions of the Susquehanna River Basin, it is more than likely that drillers would take advantage of the opportunity to withdraw water from the Delaware River Watershed for fracking.

The management, protection, and conservation of water resources is DRBC's *raison d'être*. One of the few regions to be governed by a Compact based on watershed boundaries, predating our federal environmental laws and bureaucracies, DRBC is in a unique and powerful position to make watershed-based decisions from which the Basin states have richly benefited since 1961. Indeed, little is being done regarding proper management and protection of water nationally or on a global scale, evidenced by the high water consumption and out of date planning that dominates the world's approach to water.

Examining the demand for water worldwide, a report published in August in *Nature* concludes that we are overexploiting our aquifers, estimating that the global groundwater footprint is about 3.5 times the actual size of aquifers where almost one quarter of the world's population lives (1.7 billion people).[cxix] An article in the Harvard Business School's Working Knowledge points out that by 2050, the Earth's population will likely exceed 9 billion people, many expected to live in cities yet in terms of urban planning, "Water is often planned last and gets short shrift," said John Briscoe, a professor at the Harvard School of Engineering and Applied Sciences, who participated in a panel a session dedicated to water. "Water is absolutely the poor cousin of the utilities."[cxx]

Water used for fracking, particularly in deep geologic formations, is a depletive use and is defined as depletive by DRBC. This depletion is fundamentally different than evaporative losses for agriculture, electricity generation, and recreational uses like golf courses, which essentially recycle the water used into the atmosphere where it returns as precipitation. In fracking, the water used is not only removed from its source, but is locked away in the rock formations where it was injected. In the Marcellus Shale, approximately 90% or more of the water stays below the ground and the remainder (10% or less) travels back up the well bore during the fracking process as "produced water". That produced water has been transformed from its natural quality to a polluted state that essentially renders it useless as a water source, and becomes wastewater that is required to be disposed of under Clean Water Act regulations. The majority of the water injected for fracking is locked away from the earth's natural hydrologic cycle, a total loss that simply doesn't return to the atmosphere, except perhaps over geologic time frames, in a highly polluted condition.

The ecological and socio-economic implications of this true depletive loss have not been studied or quantified, but considering the finite nature of potable water and our expanding consumption rate, this must be recognized by DRBC as a key element in assessing fracking's water footprint and how it impacts the Basin's water "balance sheet". Very little data exists to quantify groundwater in many aquifers[cxxi], even within the relatively well-studied Delaware River Basin, so that accurate water footprint accounting and its implications for meeting existing and future water demands while maintaining water quality standards just isn't available. This should be a huge caution sign for DRBC that supports a total prohibition on this depletive use.

The amount of water used to frack a shale gas well in Pennsylvania has more than doubled since 2011. In 2017, the average amount of water used was 11.4 million gallons per Marcellus Shale well in Pennsylvania. (FracTracker Alliance, "Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin", March 20, 2018)

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

The lengthening of horizontal well bores due to advances in drilling technology has created a trend in the drilling industry that has dramatically changed the water footprint of fracking in the Marcellus and Utica Shales. The DRBC estimate in its Supplementary Information of an average 4.3 million gallons per well per fracturing event based on SRBC data from 2008 and 2013 and a median 4.18 million gallons reported by EPA for Pennsylvania between 2011 and 2013, are now out of date. DRBC states that EPA also reported that in at least 10% of the cases, 6.6 million gallons was used per well in Pennsylvania. DRBC states that the longer well bores that began in 2016 increased the average water use per fracturing event to approximately 5.1 to 6.5 million gallons. The current data shows an even greater average use per Marcellus well in Pennsylvania than DRBC's estimates – 11.4 million gallons of water on average per fracked Marcellus shale well. (FracTracker) This is a sea change in terms of potential water resource impacts.

News articles are reporting large well pads with wells that have longer and more well bores in western Pennsylvania's Marcellus Shale region, with horizontal bores traveling up to four miles and curving away from the vertical well bore at shallower depths and less radical curvatures to allow for more horizontal bores that won't interfere with each other, multiplying the capacity of each well.[cxxiii] Industry reports consider the longer well bores and supersized pads to be a better investment and the direction that shale gas well development is going.[cxxiv]

The amount of water used today to frack a shale well in the Appalachian basin also has been calculated to use significantly more water per lateral foot. (FracTracker) This phenomenon is being reported in industry filings but the reasons have not been analyzed publicly. This is another important change, however, that could increase the amount of water used for fracking shale gas wells and should be considered as a driver for demand. Overall, the potential impact of water depletion to meet this demand has at least doubled and the trend is for the demand to continue to increase per well drilled, making the impacts greater.

Another factor that influences the amount of water needed by drillers to develop shale gas wells is the induced expansion of the market for gas due to the buildout of infrastructure such as pipelines and end uses that include the export of gas and gas liquids and the consumption of natural gas at new gas-fired electric generating stations and petrochemical processing facilities.

The U.S. Energy Information Administration reported in March 2018 that the nation's liquefied natural gas (LNG) exports quadrupled in 2017. "The increase in LNG exports over the past two years is the result of the continuing expansion of U.S. LNG export capacity. Two LNG projects—Sabine Pass in Louisiana and Cove Point in Maryland—have come online since 2016, increasing U.S. LNG export capacity to 3.6 Bcf/d. Four more projects are scheduled to come online in the next two years: Elba Island LNG in Georgia and Cameron LNG in Louisiana in 2018, then Freeport LNG and Corpus Christi LNG in Texas in 2019. Once completed, U.S. LNG export capacity is expected to reach 9.6 Bcf/d by the end of 2019. As export capacity continues to increase, the United States is projected to become the third-largest LNG exporter in the world by 2020, surpassing Malaysia and remaining behind only Australia and Qatar."[cxxv]

This illustrates the expansion of the LNG market which is spurring new fracked gas well starts in Pennsylvania as well as other states. The proximity of Pennsylvania to the Cove Point LNG export facility in Maryland (in the Chesapeake Bay) will increase close-by demand for more gas. Also, demand for gas to be processed and marketed as natural gas liquids (NGL) at export facilities will grow as well. An example is the expanding Sunoco Logistics export terminal in Marcus Hook, Pennsylvania south of Philadelphia on the Delaware River; a second Market East pipeline is under construction to bring more natural gas liquids from the Mark West processing facility in southwestern Pennsylvania to the Delaware River terminal for export. There is also an active application to build a new NGL export facility in Greenwich Township, Gloucester County, New Jersey on the Delaware River, across from Philadelphia. PADEP has permitted 49 new natural gas-fired power plants in the Commonwealth in recent years which will also increase demand for fracked gas wells. DRN received documentation of the number of permitted natural gas power plants from PADEP in late 2017 through a Right to Know Law request and the excel sheet provided by PADEP in response is linked in the Endnotes.[cxxvi]

The number of shale gas wells drilled in 2017 increased by 35 over the year prior in Pennsylvania and, as delivery systems and markets grow, the price of gas will go up, making it more profitable to drill new wells. (Fractracker)

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

All of this activity means an increased demand for water for fracking in Pennsylvania. Looking at 2017 alone, 6 billion gallons of fresh water was used in Pennsylvania to frack wells. (FracTracker). That is approximately 16.5 million gallons of water per day, a depletive use. If the amount were to remain steady (rather than increase per well as the trend expects) the fracking industry will be looking for fresh water sources to fill their need and can be expected to look to the Delaware River Basin, especially for the areas in proximity to high-producing wells such as those located near the Delaware River Watershed in northeast Pennsylvania. The amount of water demand for fracking from nearby wells could easily dwarf the current depletive water use of fresh water in the Upper Delaware River Basin.

> "In an industry expecting to drill roughly 45,000 more wells just in the Interior Marcellus Formation of PA through 2045,24 the pressure to find new water sources and waste disposal sites will be ongoing in the coming decades, including within the Delaware River Basin. This will require over half a trillion gallons of water to stimulate, assuming that the per-well water consumption does not continue to increase beyond 2017 figures."[cxxviii]

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

Water withdrawals from surface and groundwater have substantial impacts on water resources, ecosystems, and stream habitats. Human activities that effect these resources have severely altered the natural environment and continue to do so. 30-35% of all freshwater fish species are believed by scientists to be already extinct, with 93% of those reductions occurring in the last 50 years. This shows an accelerating trend towards extinction. Freshwater mussels is one of the most imperiled animal groups in North America. The dwarf wedgemussel, a federally endangered species, has established populations in the Upper Delaware River Watershed (Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018)

> "The dramatic impact of human-induced alterations on freshwater flora and fauna is widely reported (Gleick et al., 2001; UNEP, 1999). Running water ecosystems belong to the most severely human-impacted habitats on Earth (Nilsson et al., 2005; Malmqvist and Rundle, 2002). Of more than 3,500 species currently threatened with extinction worldwide, one-quarter are fish and amphibians.
>
> In freshwaters, the projected decline in species diversity is about five times greater than in terrestrial ecosystems (Pimm et al., 1995). This rate is similar to that of great prehistoric extinctions (Malmqvist and Rundle, 2002).
>
> It has been suggested that some 30-35% of all freshwater fish species are already extinct or in serious decline worldwide (Stiassny, 1999). Ninety-three percent of these

reductions occurred during the last 50 years, indicating extinction of freshwater fishes is a serious and accelerating global trend (Harrison and Stiassny, 1999).

The freshwater mussel is one of the most imperiled animal groups in North America with only 25% of the existing species having stable populations (Williams et al., 1995). Freshwater mussels fulfill many crucial ecosystem services such as the filtering of large amounts of water, which removes pollutants from the water. Hence, healthy assemblages of mussels are necessary to maintain high water quality standards."[cxxx]

Urbanization is playing a large part in the destruction of natural flow patterns in streams and habitat loss. Excessive water withdrawals and deforestation that alter hydrograph runoff patterns that increase peak flows and decrease base flows of streams are a large part of the changes accompanying urbanization that are causing species extinction and destabilization. (Parasiewicz)

"Historical and ongoing urbanization of our landscape intensifies floods and droughts, causing damage to human property and stressing the fauna. Excessive water withdrawals due to human and industrial demands dry up rivers with increasing frequency.

The process of urbanization alters seasonal hydrographs by increasing peak flows and decreasing base flows (e.g., Bedient and Huber, 1988; Dunne & Black, 1970; Parasiewicz and Goettel, 2003; Petersen, 2001). In the Northeastern United States, this hydrological pattern appears to be a regional phenomenon and a lasting legacy of historic deforestation. Even in areas such as the Catskill Mountains that superficially

> appear to have recovered from the historical impacts of earlier timber harvests, similar effects can still be observed (Parasiewicz et al., 2010)."[cxxxi]

Reduced base flows that result from these changes warm up the water in a river or stream more quickly. Groundwater withdrawals translate into less cold water being expressed to the surface and to waterways. Summer temperatures in excess of 89 degrees F are now being recorded in "long stretches of coldwater streams." (Parasiewicz) These impacts harm species and also degrade water quality. Scientists are warning that, coupled with climate change impacts that are causing higher summer temperatures, longer warm seasons, lower river flows, and more frequent and more severe flooding, the risk of further degradation and extinctions are so great that water withdrawal management must be a priority. (Parasiewicz) A species such as the dwarf wedgemussel, which is sedentary, is particularly vulnerable to habitat changes that can result from water withdrawals at sensitive times or rapid fluctuations in flow. (Parasiewicz)

> "The water in these reduced flows tends to warm up more quickly in rivers that have been widened by previous floods and historical logging operations. Shallow ponds, created by thousands of small dams, serve as natural solar collectors. Additionally, less cold water is entering the rivers from base flow because of increased ground water withdrawals. We are frequently now measuring summer water temperatures in excess of 80°F in long stretches of "coldwater" streams (e.g. Ballestero et al., 2007, Parasiewicz et al., 2007).

The change in our global climate further contributes to this impact by causing higher summer air temperatures, a longer summer season, and lower minimum river flows together with more frequent and severe flooding (Faloon and Betts, 2006).

Consequently, the habitat conditions are quite unstable and high water temperatures have caused fish die offs and potentially reduced mussel populations in the past. As documented by an investigation of dwarf wedgemussel habitat, the existing populations are limited to a few locations that maintain hydraulic stability. The sedentary organisms like freshwater mussels are particularly vulnerable to the habitat reduction due to the lack of water than can be caused by water withdrawals or rapid fluctuations."[cxxxii]

Water withdrawal management, however, is not a simple matter that can be addressed effectively by setting minimum flow levels based on the Q7-10 (the flow which occurs for a period of seven consecutive days one time in 10 years – considered "drought flow") or simply managing the scheduled releases from reservoirs and dams. (Parasiewicz) Scientists have discovered that the hydrologic pattern of a flowing water body are critical and if disrupted can be detrimental to aquatic life. (Parasiewicz) Preserving the natural or ecological flow regime of a waterway is of utmost importance in terms of stream health, habitats, water quality and species and must be the basis of decisionmaking regarding water withdrawals if these are to be adequately protected.

"Silk et al. (2000) eloquently suggests that "The natural ecosystem of any river is the product of millions of years of adaptation and evolution, which have created a myriad

> of variables and subtleties more complex than we can imagine." Due to this complexity and continuing conflicts of interest among competing water uses, a very precise planning and evaluation of potential development impacts is required.
>
> Water allocation issues are not new, and many techniques have been developed in recent decades to address these problems (Stalnaker, 1995; Dunbar et al., 1998). Only recently we learned to recognize that not only is the quality and quantity of water released below a hydro-power or irrigation dam important, but also that modifications of hydrological patterns can have detrimental effects on aquatic life (Richter et al 1997)."[cxxxiii]

In the Delaware River Basin, the Upper Delaware's Catskills and Pocono Mountains are generally rural with steep areas that have shallow soils overlaying bedrock. (Parasiewicz) Severe erosion can occur when there are high flows in a stream, eroding stream banks and widening the stream to unnatural widths. The adverse changes in stream morphology are exacerbated when woody debris is removed or high flows scour debris away. (Parasiewicz)

> "The Catskill Mountains' and Poconos watersheds are generally rural, topographically steep areas with shallow, permeable soils overlaying restrictive bedrock or fragipans. Heightened flow peaks cause severe erosion, leading to the down-cutting and over-widening of river corridors (Parasiewicz et al., 2010). The notable lack of woody debris structure documented in the Stony Clove Creek study in the Catskill Mountains (Parasiewicz et al., 2003) was partially a consequence of increased flow peaks removing log jams before they can stabilize, but also due to frequent "cleanups" of woody debris as a flood protection and beautification measure."[cxxxiv]

Shallower, wider and straightened streams add to the factors that heat up waterways. Anchor ice also tends to form in winter in shallower streams, sticking to the bottom and damaging aquatic fauna and forcing fish to move, increasing mortality. This becomes a downward spiral for the life of a stream when reduced base flow and groundwater levels caused by excessive and poorly timed water withdrawals disrupt critical natural flow patterns. (Parasiewicz)

> "These changes, in combination with reduced stream flows and groundwater levels, increase summer water temperatures and can cause creation of anchor ice in the winter. Anchor ice is an ice forming at the bottom of the river that can create considerable damage to the aquatic fauna by forcing fish movements and increasing their mortality. In addition, many river corridors, especially those in urbanized areas, have been physically modified (e.g., straightened, widened, dredged or impounded), altering the character of the corridor (e.g. from braided to straightened) and leading to further modifications in the hydrological regime (Hewlett and Hibbert, 1967)."[cxxxv]

One of the results of the hydrologic pattern changes, the disruption of the natural flow regime, is the loss of species that were adapted to the unique habitat conditions that allowed them to live in a location. More generalized species move in that can adapt to the changed conditions, as documented in northeastern rivers. (Parasiewicz)

> "The most apparent consequences of such changes in hydrological patterns are a reduction in fish densities and modification of the fish community structure from specialized riverine species towards more generalized species. This phenomenon has

> been documented in several recent studies in the Northeast Region (e.g. Parasiewicz and Goettel, 2003; Armstrong et al., 2001)."[cxxxvi]

DRBC does not explain how the measures it expects to "discourage" water withdrawals will be carried out. The lack of detail about how biocriteria will be assessed and used to protect flows and species is not disclosed in the draft regulations but must be in order for the public to understand and comment on the draft regulations. (Schmid)

> "DRBC has not explained how it intends to implement the requirements of its *Water Code* and *Water Quality Regulations* when authorizing stream water withdrawal for HVHF uses. In particular, it does not indicate how it will assure compliance with its adopted biocriteria. Those biocriteria appear not to be addressed by other agencies. DRBC has offered no detailed regulations or technical guidance specifying how such assessments will be made and reported in order to fill the current regulatory gap."[cxxxvii]

DRBC proposes to allow out-of-basin water withdrawals for fracking, despite its "discouragement" of out of basin transfers and its recognition and regulation of such withdrawals as depletive. DRBC implies that its low-flow and pass-by flow policies for water withdrawal dockets will sufficiently protect the Watershed's streams and rivers. This is not so. DRBC regulates withdrawals from streams with the use of a "pass-by flow" that limits the amount of water that can be withdrawn to protect streams from being overdrawn. However, a pass-by flow that is based on using the Q7-10 (the flow which occurs for a period of seven consecutive days one time in 10 years – considered "drought flow") is not adequate to protect waterways and the life that depends on them[cxxxviii] and can be expected to cause direct harm to the habitats and water quality of the stream.[cxxxix]

Using the Q7-10 allows the stream‘s flow to be artificially “flattened” because the natural flow regime and seasonality will be disrupted and potentially eliminated. An ecological flow analysis of the waterway is required to measure the natural variation of the waterway’s flows in terms of volume, rate, temperature, stream stricture, and quality. This analysis should be completed before any withdrawal of surface water in order to provide an ecologically-based flow regime that will give needed protection to the habitats, species and water quality of that particular stream. Once a comprehensive assessment is complete, reliable models can be used to forecast changes should withdrawals for any purpose be contemplated. (Parasiewicz) Ecologically-based flow requirements, stream channel restoration projects and mitigation projects, will then be able to be designed to retain the habitats needed by the River’s species. (Parasiewicz) This is essential to protect habitats and to ensure water quality that will support the river’s uses and values.

> “Before contemplating any option associated with potential water withdrawals of any kind it would be necessary to conduct a comprehensive assessment of habitats and species in tributaries and main stem and to develop watershed models to forecast potential cumulative impacts. Such models need to inform the decision not only with regard to the possibility of water withdrawals, but also about necessary mitigation and compensation measures such as by-pass flows or channel improvements. Such documentation and models do not exist yet.”[cxl]

Water withdrawals from surface waterways also have the potential to deplete downstream groundwater resources if set based on pass-by flows that do not take seasonality into account, including local benefits of high flows such as springtime flows or heavy precipitation events. Such a withdrawal may downstream cause some additional discharge from the aquifer to make up the loss of stream flow. This additional base flow will be contributed by shallow groundwater downstream of the withdrawal site, impacting aquifers. This presents the potential for loss of groundwater reserves that will discharge to the stressed waterway to attempt to maintain base flow that was lost to the withdrawal.[cxli]

The Delaware River is an exceptionally healthy river that supports the federally endangered dwarf wedgemussel and several other freshwater mussels, and many migratory fish that travel to the upper reaches of the river, including the American eel and American shad. (Parasiewicz) These are iconic species for the Delaware that define its nature and distinguish it as unique and of national importance, enabled by the river's free flowing main stem, the longest free-flowing river east of the Mississippi. The river is enjoyed by millions due to the nearby New York and Philadelphia metropolitan regions that can drive there on a tank of gas. Fly fishing in the coldwater creeks and streams are famous and beloved for generations. (Parasiewicz)

The river has been recognized by Congress as a Wild and Scenic River, among the early rivers to receive this merit, due to its outstanding natural features and scenic and recreational values. The National Park Service protects the Upper Delaware and the

Delaware Water Gap National Recreation Area, one of the most frequently visited in the nation.

But the Upper Delaware's streams still show the imprint of human activity in the long-lasting effects of historic deforestation and heavy industrial practices from the last centuries on its creeks and streams that are shallow, wide, and flashy, exhibiting dramatically altered hydrologic patterns due loss of natural flow regimes. (Parasiewicz) The export of water from the Upper Delaware for drinking water in New York City has indelible impacts. (Parasiewicz)

> "However, the legacy of deforestation and an industrial past is still visible in its over-widened, shallow river channels and flashy hydrology with rapidly changing flows from very low to very high. The watershed is also under pressure for hydropower use and as a drinking water supply for New York City (Parasiewicz et al., 2010)."[cxlii]

Water withdrawals of freshwater totaled about 4,130 Mgal/d in 2010, with New York City withdrawing an average 574 million gallons per day.[cxliii] Up to 17 million people receive their drinking water from the Delaware River, varying between 15 and 17 million on any given day depending in large effect on how much is exported to New York City through the reservoir and aqueduct system.

Pumping of aquifers to remove water for depletive/consumptive use can diminish surface water supplies by reducing natural shallow groundwater flows to streams and reservoirs. It also has the potential to disrupt the flow of groundwater that feeds existing water supply wells on which millions within the Basin rely for drinking water and other local uses. It can also diminish and/or disrupt available groundwater that supports forests and other vegetation, including agriculture, harming existing uses. Natural resources such as wetlands, seeps, and springs, are also diminished or seasonally depleted by depletive water withdrawals.

Managing the Delaware River flows downstream of the major reservoirs on its tributaries is a complex and difficult task. The Supreme Court Decree that prescribes the division of water among the four states, the minimum flow targets that must be maintained in the main stem river, and the Court's mandate to repel the salt line in the tidal river to protect drinking water intakes in Philadelphia and southern New Jersey as well as the flow regimes that are required to protect fish and aquatic life in the Upper Delaware, all present challenges that sometimes lead to unstable water temperatures and fish die-offs as well as threatening the river's dwarf wedgemussel populations. (Parasiewicz)

> "The flows in the river are strongly influenced by releases from upstream reservoirs: Cannonsville on the West Branch, Pepacton on the East Branch, Wallenpaupack on the Lackawaxen River, Mongaup on the Mongaup River and Neversink on the Neversink River. A Supreme Court decree was needed to manage the downstream salt wedge in Philadelphia by mandating the minimum flow releases. Due to complex management objectives, the current flows in the river can be erratic and unpredictable.
>
> Consequently, the habitat conditions are quite unstable and high water temperatures have caused fish die offs and potentially reduced mussel populations in the past. As

documented by an investigation of dwarf wedgemussel habitat, the existing populations are limited to a few locations that maintain hydraulic stability."[cxliv]

The Flexible Flow Management Plan, a major agreement between the Decree Parties, is an ongoing plan that has recently been renewed after intense negotiations; it is a crucial endeavor that requires further work to develop adaptive management strategies to protect life in the streams and Upper River. (Parasiewicz)

> "In consequence of a multiyear collaborative efforts the next Flexible Flow Management Plan including measures to protect federally endangered species such as the dwarf wedgemussel has been recently extended for another 5 years. It is a complex effort and intensive endeavor aiming towards managing numerous users and protecting the river ecology. During this time the DRBC and involved parties committed to continue investigations of the consequences of plan introduction searching for adaptive management options."[cxlv]

All water withdrawal decisions must be informed by the Flexible Flow Management Plan and the methods that are developed to manage the river's flows to protect the Watershed's habitat and species. The depletive removal of water from the river jeopardizes the competence of the plan and the protections it is supposed to provide. (Parasiewicz)

> "HVHF requires high volumes of water (between 4 to 11 million gallons per fracturing event on one well only). Such withdrawals could easily destabilize the carefully crafted web of Flexible Flow Management Plan and other protective regulations."[cxlvi]

The proposal to allow water to be exported from the Basin for fracking does not sufficiently take into account the water scarcity that DRBC describes in times of drought and low rainfall. Well pads outside of the Basin will likely be encouraged in close proximity to the Delaware River Watershed boundary to take advantage of the availability of water, especially when new sources are sought for fracking in regions already being heavily tapped. (Parasiewicz)

Managing the water flows and protecting the outstanding values and living systems that make up the Delaware River is complex and DRBC is just now beginning to take up the development of adaptive strategies and ecological flow consideration in its Flexible Flow Management Plan work and the research that the Regulated Flow Advisory Committee and Subcommittee on Ecological Flows (SEF) will be doing. The fluctuations of weather and the added stresses of climate change such as increased frequency and intensity of storms and the environmental degradation that results, demand more comprehensive and ecologically-based management strategies. It is counterproductive to allow water exports that will impact flows, groundwater reserves, and stream stability by permitting further depletive uses. This fracking-related activity must be avoided to achieve success in the endeavor to both protect and manage the river and its ecosystems. (Parasiewicz)

> "A thorough review of existing information made it clear that complete prohibition of shale gas extraction is an appropriate decision for protection of public health and resources in the Delaware River Basin. This prohibition, however should also include water exportation from and wastewater imports to the Watershed. Offering permitting

options will encourage development of extraction wells in near proximity of the Delaware Watershed imposing the public and wildlife to associated risks. Particularly the substantial uncertainty with long term effects of the pollutants in produced water and our ability of stopping them from entering into the waters of the area calls for very strict regulation without permitting options."[cxlvii]

"However, the Commission is willing to consider permitting *water exports* for utilization in hydraulic fracturing. Although the Commission requires also alternative analysis, in face of the ample evidence of water scarcity in the Delaware River Watershed this consideration seems to be inconsistent with declared policy of discouraging the exports."[cxlviii]

"The Upper Delaware River Watershed is a precious resource with a multitude of outstanding characteristics and users. The maintenance of the watershed's ecological integrity requires careful and wise management. Such management is under development and measures that prevent degradation of aquatic fauna under climate change scenarios are not in place yet.

At this point adding more complexity and additional risks before such a program is in place is counterproductive, as obviously more time and resources are necessary to complete ongoing scientific efforts and take control over current issues in a way that will allow the protection and enhancement of ecological integrity.

Therefore, I recommend that Natural Gas Development should be fully banned without encouraging HVHF activities, especially in the proximity of the Delaware River

Watershed. This includes complete prohibition on water exports and wastewater imports for the purpose of natural gas mining as an unnecessary risk to the wellbeing and health of millions of citizens and the Delaware River Watershed's water resources and natural ecosystems, including the species that live there."[cxlix]

DRN recommends that a change be made to the text of Section 440.3 (b) to include all gas drilling and fracking regardless of whether it is High Volume Hydraulic Fracturing (HVHF), as defined at Section 440.2, or not. DRN bases this recommendation on the fact that "conventional" gas drilling, as defined by Pennsylvania Department of Environmental Protection, has substantial adverse impacts on water, the environment, and public health, where it is occurring today, as discussed in the review of scientific reports in this Comment. Furthermore, fracking and drilling that uses less than 300,000 gallons of water still has the potential for a substantial effect on the water resources of the Basin due to the toxic and radioactive properties of the fluids that are injected and the produced water or flowback that is generated by all drilling and fracking carried out to develop natural gas.

Comment Opposing Wastewater Transfer, Treatment, Storage, Disposal and Discharge of Produced Water and CWT Wastewater Produced by Fracking as Proposed at Section 440.5

DRN opposes the importation, transfer, treatment, storage, disposal, or discharge in the Basin of produced water and Centralized Waste Treatment (CWT) wastewater generated by fracking operations, as proposed at Section 440.5. DRN supports the complete prohibition of these proposed activities.

DRBC has recognized many of the problems posed by the wastewater produced by fracking in its Supplementary Information. However, the draft regulations do not provide protection and effective management of the water resources of the Delaware River Basin. The only option that will allow DRBC to meet its obligation to protect the water resources of the Basin is to prohibit these wastewaters and produced waters from being stored, processed, treated, disposed or discharged within the Basin.

There is ample evidence that supports a complete prohibition of the storage, processing, treating, disposal or discharge of produced water and CWT wastewater within the Basin.

The highly toxic nature of frack waste is widely recognized. According to the GAO, produced water is “generally of poor quality, with levels of contaminants varying widely”.[cl] Fracking can yield poorer quality produced water than other extraction processes.[cli] A previous study from the U.S. Department of Energy concludes that produced water from gas drilling is 10 times more toxic than those from off shore oil drilling.[clii] Adding to pollution dangers posed by the reuse and recycling of frack fluids mixed with flowback or produced water, Marcellus Shale contains radionuclides including uranium-238, thorium-232, and their decay products. Radioactive concentrations in the Marcellus Shale formation are at concentrations 20 to 25 times background, making shale gas wastewater extremely radioactive.[cliii] The produced water from Marcellus Shale has higher levels of radionuclides than water from Barnett Shale wells, according to the GAO.[cliv] Sampling and data-gathering by New York State detected radiological parameters in Marcellus Shale flowback, including

Radium-226[clv], the longest lived isotope of radium with a half-life of 1600 years. Radium 226 can cause lymphoma, bone cancer and blood formation diseases such as leukemia and plastic anemia. Gross Alpha, Gross Beta, Total Alpha Radium and Radium-228 were also found.[clvi]

New York's DSGEIS contained a list of constituents in Marcellus Shale wastewater from Pennsylvania and West Virginia.[clvii] Many are hazardous, some have known harmful health impacts, and some are carcinogenic. New York tested flowback from these shale gas extraction operations in Pennsylvania and West Virginia and found 154 parameters.[clviii] DRBC proposes to require Treatability Studies for the treatment of frack wastewater at Centralized Wastewater Treatment Facilities that plan to discharge to the Watershed. These studies are supposed to show that the "Pollutants of Concern" are treated, using USEPA Tables from the agency's technical document on oil and gas waste discharges to define the "Pollutants of Concern".[clix] There are 78 pollutants listed but those are not all the toxic and/or hazardous pollutants contained in frack wastewater. For instance, Tables C -11, C-13, C-15, C-17, and C-19 don't include all the 154 parameters that New York discovered in their sampling. We know from DRBC and many other sources that over 1000 additives are in the fluids used to frack wells today,[clx] and many, according to U.S. EPA and other authorities, are carried into the frack wastewater produced by the well.

Wastewater produced by fracking contains many dangerous and toxic constituents and properties including: Total Dissolved Solids (TDS), Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen, Nitrate–N, Chloride, Bromide, Sodium, Sulfate, Oil and Grease, BTEX (benzene, toluene, ethylbenzene, xylene), VOC (volatile organic compounds), Naturally Occurring Radioactive Materials (NORM), Barium, and Strontium, according to a report by Natural Resources Defense Council.[clxi] Some are carcinogenic, some have known health effects, and some are toxic to aquatic life and plant life.

Yale University School of Public Health, in a study of chemicals used in fracking, found that of the 119 compounds with sufficient data to classify them in terms of carcinogenicity (only 20% of chemicals in use had sufficient data – a problem in itself), "44 percent of the water pollutants and 60 percent of air pollutants were either confirmed or possible carcinogens."[clxii] Fifty five unique compounds with carcinogenic potential could be released to both water or air and 20 chemicals had evidence of increased risk for leukemia or lymphoma specifically.[clxiii]

In its national study of fracking and drinking water, EPA identified 1,606 chemicals in fracking fluid or drilling wastewater including 1,084 identified in fracking fluid and 599 identified in wastewater, yet only 173 had toxicity values from sources that met EPA's standards for conducting risk assessments. "This missing information represents a significant data gap that makes it difficult to fully understand the severity of potential impacts on drinking water resources." However, EPA also reported that "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."[clxiv] It is instructive to note that EPA did not mention that the agency's own failure to request health testing for new chemicals proposed for oil and gas drilling and regulated by EPA under the Toxic Substances Control Act contributed to the lack of information about chemical risks.[clxv]

EPA officials could not be certain about the accuracy of their list of chemicals found in fracking fluid and wastewater in part because the list did not include confidential chemicals used by drilling companies for hydraulic fracturing. Drilling companies have withheld fracking chemical identities from the public as confidential thousands of times.

Two Harvard researchers found that 92 percent of the well-by-well fracking chemical disclosures submitted to the non-governmental organization FracFocus between approximately March 2011 and April 2015 included at least one chemical identity withheld from the public as confidential business information (CBI).[clxvi] FracFocus is the nation's leading repository of fracking chemical disclosure information and currently contains disclosures from more than 127,000 wells.[clxvii] EPA commented that, "when chemicals are claimed as CBI, there is no public means of accessing information on these chemicals. Furthermore, many of the chemicals and chemical mixtures disclosed, or those detected in produced water, lack information on properties affecting their movement, persistence, and toxicity in the environment should they be spilled."[clxviii]

There may be constituents in flowback and produced waters from gas development that are not regulated under the Safe Drinking Water Act even though they have human health risks and ecosystem/environmental impacts. Some substances are chemicals that are unregulated and for which there is no maximum contaminant level (MCL) yet set by U.S. Environmental Protection Agency (EPA) or the State for drinking water quality. Many of these are known as “emerging contaminants” and have known harmful human health effects but standards are still in the process of being developed. These pose additional unacceptable risks because they may be released into the environment without detection or any requirement for monitoring, detection, or treatment. Some of these are endocrine disruptors (EDC) or pharmaceuticals that may occur in gas drilling wastewater.[clxix]

EDCs used in hydraulic fracturing fluids and found in flowback are of special concern due to the biological effects of these constituents at extremely low concentrations. Suspected EDC’s found in gas drilling wastewater include arsenic and selenium; hydraulic fracturing fluids may contain others such as 2BE, 2-Ethylhexanol, and Crystalline Silica. Scientists and health professionals are beginning to analyze these materials and measure their impacts on human health in a different way, testing these compounds at very low levels in the range of human exposures and at various endpoints.[clxx]

In an effort to protect human health from these very dangerous materials, scientists are concluding that there are no safe doses for endocrine disrupters; the fact that they have biological effects proves that EDC’s have biological activity – what the induced effects are is the question.[clxxi] As stated by Linda Birnbaum, Director, National Institutes of Health, “It is time to start the conversation between environmental health scientists, toxicologists, and risk assessors to determine how our understanding of low-dose responses influence the way risk assessments are performed for chemicals with endocrine-disrupting activities. Together, we can take appropriate actions to protect human and wildlife populations from these harmful chemicals and facilitate better regulatory decision making”.[clxxii]

There are other problems that make it impossible to accurately test for and remove toxic constituents of wastewater and produced water generated by fracking. According to a report that the Partnership for Policy Integrity published in 2016 based on a Freedom of Information Act (FOIA) request filed with EPA, between 2009 and 2014, EPA reviewed 105 new chemicals proposed for drilling and fracking for health and environmental risks under the New Chemicals program.[clxxiii] EPA had health concerns about 88 of the chemicals ranging from irritation to skin, eyes, and mucous membranes; lung effects; neurotoxicity; kidney toxicity; and developmental toxicity.[clxxiv]

Nevertheless, EPA allowed 98 of the 105 to go into commercial production, often without health testing data that could have more conclusively determined health risks; more than half of these chemicals went into commercial production and use.[clxxv]

Chemical manufacturers frequently withheld as trade secrets information about the chemicals' identities including Chemical Abstracts Service Numbers, chemical names, and trade names. This confidentiality makes it very difficult to know where these chemicals have been used but we do know they are used in Pennsylvania's Marcellus Shale wells.[clxxvi]

It is likely that drilling companies would use secret and potentially dangerous chemicals if drilling and fracking were allowed in the Basin. And it is likely if wastewater discharges are allowed, these secret chemicals will enter the Watershed's environment and contaminate its water.

The EPA has found that fracking wastewater can contain chemicals injected in fracking. Therefore, if fracking wastewater is allowed in the basin, it is likely that treatment facilities will be handling and discharging unknown and potentially toxic contaminants that not only are not identified in the permit or docket as requiring treatment but may not even be sampled for.

This opens a pathway of pollution that is extremely dangerous because the presence of the chemical and its concentration in effluent would be unknown, allowing it to slip past treatment and enter receiving waterways as well as potential air emissions or sludge residues. If the facilities don't know what they're trying to remove from the water, they are unlikely to remove it.

The end result will risk contamination of the Basins' water resources, including drinking water supplies. The only way to eliminate the outsized risk of exposing people, wildlife, and the environment to this contamination in drinking water and through other environmental pathways is to prohibit its storage, treatment, processing, disposal, and discharge in the Watershed. (Miller)

> "The range of hydraulic fracturing additives is very large, and difficult to assess from a risk perspective, since the list is almost certainly incomplete, specific information on the chemicals is lacking, and the specific rate of usage is not offered. Thus, not knowing the composition of the specific additives and the amounts provides effectively no basis for estimating the risk of these components on the biota of the receiving water. A mere laundry list of these components does not meet requirements for analysis of their potential impacts. The list is so long, and the data on each component so meager, that it falls far short of an analysis of risk. Additionally, many additives used are given

proprietary trade names, and while the regulators may have information on the constituents in those products, the public does not, and thus the public cannot legitimately understand the risk of these products. Additionally, treatment of those proprietary compounds, even in a CWT, is not understood and ultimate disposal in a surface water constitutes a risk that can be avoided entirely by requiring deep well disposal in a permitted facility outside of the Basin."[clxxvii]

DRBC's claim that they can address the pollutants in produced water and frack wastewater from Centralized Wastewater Treatment (CWT) Facilities by "treating" 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. As discussed above, there are contaminants that pose significant hazards to human health and flora and fauna, including aquatic life, that are not included in EPA's Table; that do not have water quality standards established or other regulatory limits on exposure but have known adverse human health effects and/or ecological impacts; that do not have information developed that allows them to be used in a risk assessment; or that are kept unidentified as trade secrets by industrial operators. This is an untenable situation, much different than other wastewater that DRBC regulates, and it simply cannot be remedied by DRBC's efforts.

In attempting to address the treatment of produced water and CWT wastewater, DRBC has left important and some of the most dangerous issues unaddressed or vaguely addressed with opportunities for substantial and long term contamination to occur, even if the methods in the draft regulations were to be followed. "The flowback and produced water that flows back up the wells following hydraulic fracturing is heavily contaminated, primarily with the Marcellus formation contaminants. The produced brines that are released during gas production are complex and contain a variety of problematic contaminants and represent a serious chemical contamination potential." (Miller, p. 2)

> "The Commission clearly recognizes the problems with contaminants in HF waters, particularly in the non-tidal portions of the Delaware River. However, further efforts are required for understanding all of the contaminants in the flowback and produced water, their management and disposal. Four problematic components of the flowback water and produced brines include (1) the inorganic salts (including bromide), metals and metalloids, (2) the radioactive component (NORM), (3) the organic substances (from the hydrocarbon formation) and, (4) the chemical additives that increase the efficiency of gas recovery."[clxxviii]

The largest component in the formation water by mass is salts and other organic constitutes. (Miller) Disposal of the large volume of highly contaminated water is the biggest management problem. (Miller)

> "The associated EPA study (EPA, 2016) on management of HF water shows that produced waters containing the formation water are variable in chemical composition, but include not only simple salts (e.g. sodium, potassium, chloride, bromide, sulfate, fluoride etc.) but also a variety of metals with varying frequency (cadmium, mercury, cobalt, nickel) and metalloids (arsenic, selenium, boron). Some of the constituent concentrations are very high, particularly sodium chloride, which has a mean

concentration of on the order of 10% by weight. Some samples had over 30% by weight of simple salts plus other contaminants. The extreme contamination of these wastewaters, and the high variability of contaminant levels, make these waters complicated for treatment and potential reuse, as well as for tracking and disposal. If improperly managed and released to surface or groundwater, potentially severe contamination is likely. In particular, if this contaminated water intercepts domestic groundwater or surface water used as a drinking water source, the potential exists that these sources of water may need to be removed as a domestic source. While the proposed regulations effectively may not allow discharge of these waters into a surface stream that can be used as drinking water, that appears to not be the case for the more saline portions of the Basin.

While recognizing the problems with management of this water, the Commission fails to clearly state how this water will be either disposed in a manner that protects human health and the environment, or otherwise treated to remove the contaminants. While a range of alternatives potentially exist, effectively none of these is likely to be accomplished in even a centralized waste treatment facility, and simply eliminating these waters from the Basin is the prudent alternative."[clxxix]

One of the most difficult constituents to treat in Pennsylvania's fracking wastewater is bromide. (Miller) PADEP acknowledges that bromide is a key parameter of concern in the effluent because it can form brominated disinfection by-products (DBP's) in water supplies.[clxxx] These are a drinking water hazard because of the propensity for the brominated DBP's to form trihalomethanes and haloacetic acid, which can cause cancer.[clxxxi]

An example of how difficult it is to control bromides and the far-reaching effect high concentrations can have is the Monongahela River in Pennsylvania in 2010–2011. Bromide concentrations increased significantly, leading to increases in trihalomethane and haloacetic acids from mixing with drinking water supply disinfectants. This drinking water crisis affected the drinking water for millions of people in the Pittsburgh region; see "Bromide levels in Monongahela River rose in 2010, remain high" Pittsburgh Post-Gazette[clxxxii] and "Bromide pollution persists in Allegheny River in Western Pa.," Associated Press.[clxxxiii]

Despite "treatment" that is supposed to remove this dangerous constituent and the problems it causes in drinking water, it persists as a problem. The result is that carcinogens have entered people's drinking water and preventing this exposure is not consistently achieved by today's water treatment facilities. This problem is so risky and could expose so many people to carcinogenic substances that DRBC should prohibit fracking wastewater to enter the Basin. Miller states:

> "A particular constituent that has been problematic in Pennsylvania waters receiving partially treated hydraulic fracturing water is bromide. When water is taken in to be treated as a drinking water, normal disinfection processes (chlorine and chloramine) convert bromide ion to bromide radical, which reacts with naturally occurring organic matter to produce the probable carcinogenic brominated trihalomethanes (THM). Because of the higher molecular weight of the brominated trihalomethane, the drinking

water can violate drinking water for trihalomethanes (Chowdhury, et al., 2010; EPA, 2016) Use of ozone as a disinfectant can generate bromate, a known carcinogen (Fellet, 2014)."[clxxxiv]

A highly toxic component in frack wastewater with an extremely long life is radioactive material. Yet DRBC poses no means of addressing the disposal of naturally occurring radioactive materials (NORM). (Miller)

"The Commission also certainly recognizes the issues associated with management of NORM that comes to the surface either in the flowback or the production brines. However, similar to the salt problem discussed above, no indication on how treatment to remove these materials will be conducted.

Examples of NORM concentrations are presented from flowback in the EPA study (EPA, 2016).

The level of radioactivity as gross alpha is very high, from about 18,000 pCi /L to 123,000 pCi/L. The drinking water standard is 15 pCi/L (gross alpha).

What is to be done with these waters, and what is to be done with the residual NORM, if it is removed from the produced water and the flowback water? Dilution of the brines to a drinking standard of 15 pCi/L (gross alpha) will require 1000x to 10,000x dilutions, and is unlikely to be acceptable in nearly all jurisdictions, particularly when the components that are causing the radioactivity are not specified.

Ultimately, these radioactive materials will need to be removed offsite. Where will these radioactive materials be disposed, and will they be included with the very large tonnage of salts that results from an evaporation-crystallization treatment, or will they be separated into a metal/radioactive fraction by some (unknown?) chemical precipitation process? These issues are critical for an analysis of the potential impacts of management of these materials, and the lack of a thorough analysis presents a serious problem when assessing the risk of these substances. There is effectively no discussion of how these materials will be disposed, other than a general suggestion that they would be "treated" in a centralized treatment facility. In fact, there is no demonstrated economic and chemically efficient method for disposal of these wastes which is why most of this waste is transported to a deep well disposal site."[clxxxv]

It is well known and long understood that the Marcellus Shale formation is radioactive.[clxxxvi] USGS investigated and verified high concentrations of uranium in the Marcellus. (Marvin Resnikoff, "Memorandum, DRBC Draft Regulation Comments", Radioactive Waste Management Associates, February 19, 2018) The naturally occurring radioactive material (NORM) found in frack wastewater is unavoidable - it is released through the fracking process into the flowback that comes back to the surface through the well bore as a result of a fracking event. (Resnikoff)

One of the most commonly found in frack wastewater is Radium-226, which has a half-life of 1,600 years, so it will be present in the environment for thousands of years.[clxxxvii] It is also water soluble, meaning it easily travels with water.[clxxxviii] Radium 228 and other decay products of uranium are also found in the Marcellus and its waste products. (Resnikoff)

New York State sampled and verified the presence of Gross Alpha, Gross Beta, and Total Alpha Radium in addition to Radium 226 and 228.[clxxxix] A Duke University study of a stream in Pennsylvania below a frack wastewater plant found radium 226 levels in stream sediments at the point of discharge were ∼200 times greater (544−8759 Bq/kg) than upstream sediments and background sediments (22−44 Bq/kg) and above radioactive waste disposal threshold regulations.[cxc]

Interstitial or formation water (the brine in the shale formation) can be highly radioactive (as concentrated as 15,000 pCi/L), so each time the water is reused, the radium is concentrated. This will result in TENORM, or Technically Enhanced Naturally Occurring Radioactive Materials.[cxci] Frack wastewater containing TENORM is not properly regulated by the federal government or the states due to lack of requirements for monitoring/testing for TENORM at crucial junctures in the waste stream where it should be targeted for detection and removal. For instance, the concentrated residuals that are filtered from wastewater at treatment plants can occur at levels that are so dangerous they would need to be removed to a specially designed storage facility, such as those used for nuclear waste.

DRBC states in the proposed regulations that residuals from wastewater treatment should not be affected by the treatment process but radioactive properties inevitably pose a treatment challenge that will affect both the waste liquids and solids, including residuals; the radioactivity doesn't just disappear. (Resnikoff) In addition, the lack of testing at the well site and related lack of truck signage ("placarding") that accurately reflects the level of radioactivity of the wastewater that is transported[cxcii] adds great risk to the transport of the untreated, toxic produced water or flowback from wells outside of the Basin to the Delaware River Watershed for storage, treatment and disposal.

One of the most important distinguishing problems with produced water and CWT water produced by fracking is that it contains toxic concentrations of radioactive materials that cannot be destroyed. The result is that by attempting to set standards for its treatment in the Delaware River Basin, DRBC is not controlling its release or its effects on human health and the environment but is allowing it to enter the Watershed and its drinking water at concentrations DRBC has decided are acceptable. The radioactive materials can be released as flowback, as treated effluent from a CWT plant, in drill cuttings and other solids, in residues that result from processing or treatment, and as an inert gas, radon, which is the second highest cause of lung cancer in the United States. (Resnikoff)

This is far too great a risk for DRBC to take. This potent toxicity and long lived properties of radioactive materials alone is reason enough to prohibit frack wastewater from entering the Watershed's environment. In the SPW portions of the River, the release of radioactive elements are categorically inconsistent with the "no measureable change" requirement. (Resnikoff)

> "To review, the process of hydraulic fracturing consists of drilling a well down to the Marcellus shale formation 4000 to 8000 feet below ground and then extending the well horizontally in the shale formation for up to a mile. Casings are constructed and the wells are placed under hydraulic pressure. Explosives shatter the shale formation and proppants maintain open the shattered shale formation. When the hydraulic pressure is

released much of the contaminated water, consisting of drilling fluid and interstitial water along with rock cuttings (with the consistency of coarse sand) comes to the surface. This contaminated water is stored in an adjacent pond or in tank cars. After approximately two weeks' time, natural gas continues to come up with some of the remaining water. This salty water (brine) is highly radioactive and is separated from natural gas at the surface and placed into condensate tanks or trucks. This produced water or brine contains high concentrations of total dissolved solids (TDS). As shown in the table below, the TDS concentrations increase over time. The TDS concentrations can range up to 345,000 mg/L by day 90 after the well is placed into production. At the present time flowback and production water is transported to a centralized water treatment facility (CWT). After processing, the rock cuttings and sludge are disposed in sanitary landfills and processed water is released to the environment. Under the proposed regulations the rock cuttings, sludges and processed water can be transported to the Delaware River basin and may be released to accessible waterways. The proposed DRBC regulations do not prohibit disposal of rock cuttings into landfills within the basin.

It has been known for over 50 years that the Marcellus shale formation is radioactive. In the late 1970s the USGS investigated the Marcellus shale for high concentrations of uranium. So clearly what is radioactive below ground does not become non- radioactive above ground; this is not alchemy where the radioactivity simply disappears. This radioactivity, consisting of radium-226 and 228 and decay products, is a problem faced by the DRBC in establishing regulations. Because all this radioactivity must go somewhere, the DRBC is essentially establishing regulations that set the radioactive concentrations that can enter the environment within the Delaware River Watershed.

We support some sections of the proposed regulations. We support section 440.3 which prohibits fracking within the Delaware River basin. This is important, not only for the potential release of drilling fluids and contaminated water into aquifers but also for minimizing the potential release of the radioactive inert gas radon. We also support the policy of the commission, section 440.5, that there be no measurable change in existing water quality and that the release should not create a menace to public health and safety at the point of discharge. Based on this policy, it is inconsistent that the commission will allow produced water and wastewater from central waste treatment facilities, even under regulated conditions." [cxciii]

The removal of radioactive elements from flowback and produced water is difficult and poorly carried out by treatment facilities today. DRBC presents no method for doing this in the draft regulations. (Resnikoff) Also, DRBC's stated goal of meeting drinking water standards for the discharged effluent from CWTs is essentially not practically achievable; the safe drinking water standard for combined radium 226 and 228 is 5pCi/L. (Resnikoff) Concentrations as high as 25,000 pCi per liter can be contained in produced water generated by fracking in the Marcellus Shale. (Resnikoff)

"Centralized waste treatment facilities are not a panacea. Studies by the Pennsylvania Department of Radiation Protection show that concentrations of dissolved radium that enter a CWT are approximately equal to concentrations that leave a CWT[1] (Though there are methods for removing radium from water - methods have been used extensively in uranium mills), the process is more expensive than simply releasing this contamination to the environment or into a deep well. Even if CWT's were effective, what would be the final disposal solution for sludges and solids that were created? Essentially the radium dissolved in water would be converted to a solid that can be filtered. And what would be the final disposal solution for the rock cuttings? The radioactive content of the rock cuttings ranges from 30 pCi per gram to 204 pCi per gram (the radioactive concentration of rock cuttings that were sent to the Allied landfill in Niagara County New York)[2]. Released to waterways, Duke University scientists have measured radium concentrations and stream sediments at the point of discharge 200 times greater than upstream and background sediments and above radioactive waste disposal threshold regulations. So we are mystified by what the commission is going to find in these treatability studies required in section 440.5." [cxciv]

"The commission also states that effluent shall not exceed the more stringent of EPA or the host states primary drinking water standards. For combined radium 226 and 228, the drinking water standard is 5 pCi per liter. Produced water can contain concentrations up to 25,000 pCi per liter. It will be difficult to reach concentrations as low as 5 pCi/L."[cxcv]

[1] The DEP study showed that high Ra-226 effluent releases from CWT's were 26,000 pCi/L (DEP,ES-22) equal to the high Ra-226 concentrations into the CWT's and indicating that Ra-226 was not removed at the CWT's.

[2] NYSDEC, Division of Environmental Remediation, August 2012, re. Allied Landfill, Niagara County.

The release of produced water and CWT wastewater produced by fracking into the waters of the Delaware River Basin will release radioactive materials. Even if discharged at established drinking water standards, radioactive materials can build up over time in the environment, as is shown by scientific literature and reported data. Furthermore, since the Estuary and Bay portions of the Basin are not designated as drinking water supply, these radioactive materials can be discharged at any level set by DRBC in dockets. The public will be inevitably exposed to increased concentrations of radioactive elements over the current backgrounds. This could happen with one discharge to the air or water or it could happen as radioactivity accumulates in sediments or other environmental features in the Watershed. This exposure of the public to radioactive materials will result in an increased risk of cancer.[cxcvi] The only way to avoid this inevitable health risk is to prohibit produced water and wastewater from fracking to be stored, treated and/or discharged in the Watershed. Resnikoff states:

> "While I support the Delaware River Basin Commission's (DRBC) prohibition on high-volume hydraulic fracturing (fracking), I do not support the proposed regulations of Part 440 that allow the import of radioactive waste and solids from fracking into the basin. To be clear, the oil and gas industry has a problem in disposing of fracking water and rock cuttings. To frack a well, approximately 5 to more than 11 million gallons of water are required; in 2017 the average volume of water used to frack a Marcellus Shale well in Pennsylvania was 11.4 million gallons. That is primarily because of the longer well bores, increased now from 1 - 2 miles to 4 miles or more in some areas. Some of this

drilling fluid can be recycled. But there are not enough deep disposal wells to accommodate the demand for the volume of fracking water produced. As a result, the oil and gas industry has pressured the DRBC to accept this contaminated water. Under Parts 400 the DRBC has proposed regulations for the acceptance of water from fracking and placed conditions on that acceptance. Just to be clear the DRBC could simply ban the importation of fracking water and rock cuttings, but instead have established regulations that allow that to proceed. The following specific comments are in support of some of the regulations DRBC has proposed and opposes others.

We support the commission's policy of no measurable change in existing water quality. But we strongly oppose approving centralized water treatment facilities."[cxcvii]

Hydrocarbons are contained in flowback and produced water from fracking. But they are only part of the known components such as heterocyclic amines and sulfur containing compounds and the array of unknown compounds that are routinely produced. Without knowing all components, effective treatment can't be achieved. The safe option is to prohibit the discharge to surface waters of the wastewater produced by fracking.

"Hydrocarbons present in the flowback and produced water are characteristic of fuel hydrocarbons, and are represented by (a) compounds that, in some cases, are carcinogenic (e.g. benzene, benzo(a)pyrene), (b) common solvents (e.g. toluene, ethylbenzene), and (c) the primary fuel components of natural gas, particularly methane. But, these components are only part of the mix that is contained in fracking water. Other components include heterocyclic amines, sulfur (odor) containing compounds, and an array of unknown compounds that have not yet been identified from specific wells. The characterization of these constituents before and after treatment has not been completed. Without knowing what these chemicals are, and the toxicity of each of them, it is difficult to know how to treat them. The associated risk is primarily ecological, and, again, simply eliminating discharge of HF waters is the safe option."[cxcviii]

The draft regulations are written to allow discharges of produced water from fracking and CWT wastewater to be discharged under certain conditions. For the tidal zones of the Delaware River, there are several loopholes built into the regulations that will allow the standards that are mentioned for certain contaminants to be used as goals or guidelines and not as enforceable standards. Because the application of much of the protective measures do not apply in the Estuary where drinking water is not a protected use and because mixing zones are allowed in the Estuary and Bay, these regions of the River are open to degradation of water quality, increased concentration of toxics and emerging pollutants, and the destruction of aquatic life and species that are already at great risk due to other stresses and conditions ongoing in this part of the Basin.

This is true for contaminants that would be controlled based on Background Concentrations as well. DRBC proposes, in certain circumstances, to use the "background concentration" of a pollutant, or the measurement of the existing level of a pollutant in a waterway, as the amount that a discharger of effluent must not exceed. This could protect a part of the river where there is no or a very low concentration of a given contaminant but where there are already high concentrations of a pollutant, the waterway will, effectively, be doomed to maintaining that concentration of a pollutant if the effluent discharged simply meets the background; the waterway won't have a chance to become cleaner. In the Estuary parameters such as Total Dissolved Solids and some toxics already far exceed healthy conditions and are in need of improvement.

DRBC and the states, under federal EPA regulatory requirements such as the Clean Water Act, work regularly on plans to minimize pollution and billions of public and private funds have been spent to implement pollutant minimization plans and total maximum discharge limits (TMDL) to restore healthy water quality. The background concentration method undermines those efforts, both in current DRBC permitting practices and as proposed in the Draft Regulations. Fracking wastewater discharges that meet background concentrations in already contaminated waters, will spell doom for water quality and could harm aquatic life. The DRBC should completely prohibit the discharge of wastewater produced by fracking.

Another problem is that DRBC says they have not yet developed the analytical methods, method detection limits, and quantification limits that a discharger must use to define the background concentration of a pollutant so there is no certainty about its accuracy or reliability. This is another compelling reason not to move ahead with the draft regulation.

DRN opposes the Total Dissolved Solids (TDS) standard in the draft regulations. TDS is extremely high in frack wastewater and constitutes, by sheer mass, the largest pollutant. TDS contains potent salts that must be kept below strict levels to protect water quality and aquatic life. (Miller) In such huge amounts, TDS is very difficult to keep under control. (Miller) DRBC proposes a limit of 500 mg/l of TDS, or not to exceed background, for zones of the river as far south as River Mile 95, located roughly at the southern part of the Philadelphia region. However, 500 mg/l is not protective of aquatic life. For instance, 350 mg/l TDS reduced spawning of Striped bass (Morone saxatilis) in the San Francisco Bay-Delta region, and concentrations below 200 mg/l promoted even healthier spawning conditions for fish.[cxcix] And in the Truckee River, the EPA found that juvenile Lahonton cutthroat trout were subject to higher mortality when exposed to thermal pollution stress combined with high total dissolved solids concentrations.[cc]

DRN opposes the standards and methods proposed in the Draft Regulations regarding TDS in the Estuary and Bay. In Zones 4 to 6,[cci] encompassing most of the Estuary south to the Bay and Ocean, DRBC is allowing a TDS standard of "not to exceed 1,000 mg/l" "or a concentration established by the Commission that is compatible with designated water uses and stream quality objectives". There is too much discretion given to the agency to establish the concentration and 1000 mg/l has been shown to not sufficiently protect aquatic life, as discussed above. It is not possible for DRN or the public to comment on a concentration that is unknown and proposed to be decided by DRBC on a case by case basis. Furthermore, DRBC has not committed to monitoring and reporting of numeric effluent limits; in the draft regulations, this essential oversight tool only "may" be required. These regulations should be withdrawn as incomplete as well as not protective of water quality and aquatic life.

The record of how DRBC currently calculates and sets TDS concentrations for dockets is instructive. This practice by DRBC is not reliable or protective, as shown by variances allowed by DRBC for TDS loadings from wastewater into these areas now. DRBC even has a form that a discharger fills out to explain why they can't meet TDS limits and why they need a mixing zone – it is that customary a practice. Examples of specific approvals for permits where DRBC has been lax in applying TDS limits are Global Advanced Metals Industrial Wastewater Treatment Facility, Schuylkill River, Perkiomen Creek, Swamp Creek, PA[ccii] (TDS of 15,000 mg/l) and JBS Souderton Industrial Wastewater Treatment Facility for a meat packing plant, Schuylkill River, Perkiomen Creek, Skippack Creek, PA[cciii] (TDS of 3,100mg/l).

Even when it is known that a discharger could not possibly meet required standards throughout the year due to high levels of pollution in the wastewater, DRBC currently bends the rules by allowing open lagoons to temporarily store wastewater that at certain times cannot be discharged due to conditions in the receiving waterway, such as low flows. So not only are the regulations not strict enough but DRBC already goes around the rules and allows TDS to contaminate the Estuary at damaging concentrations. To add new sources of these damaging salts is not acceptable and cannot be allowed. The only way to protect water quality, fish, other aquatic life and wildlife is to prohibit discharges of wastewater from fracking throughout the Basin.

DRBC allows broad discretion by allowing mixing zones and employing a non-standard such as "or a concentration established by the Commission that is compatible with designated water uses and stream quality objectives". (Miller) Considering that existing discharges already provide sources of contaminants that stress the quality of the Estuary, organic compounds and radioactive elements can provide unacceptable risks to species and the ecosystems of the Basin. (Miller) Miller states:

> "From my read of the proposed regulations, it appears that disposal of HF waste water will be effectively prohibited through even a centralized water treatment (CWT) facility in areas where the receiving water can potentially be a drinking water, and in the areas designated as Special Protection Waters. With a TDS limit of 500 mg/L limit, the salt load in these HF waters would effectively preclude any reasonable treatment (other than a membrane treatment) for discharge.
>
> However, on a closer reading this may not be the case for the tidal waters that have a higher TDS limit. The language in the 440.5(f) section contain words that allow a broad discretion on whether a facility can be sited in the saltier sections of the River, with discretionary terms such as "mixing zone" or "or a concentration established by the Commission that is compatible with designated water uses and stream quality objects". Existing discharges to the lower portion of the basin, from POTW and other industrial discharges already provide a source of contaminants that are of concern. While the Delaware River water quality has improved through dedicated efforts of the Commission, the lower stretch of the Delaware River Basin already receives discharges from other industries. While a pure sodium chloride discharge may not have a major negative impact on the biota of the Basin, the other constituents in HF water, including

organic compounds and the radioactivity can still provide an unacceptable risk to the ecological integrity of the Basin."[cciv]

In the Estuary drinking water is not a protected use, so safe drinking water standards don't apply, allowing less strict pollution controls. DRBC also allows "mixing zones" there, allowing pollution in wastewater that doesn't meet clean water standards to be mixed, or diluted by the waterway, before meeting a required standard. Allowing his practice with the highly toxic wastewater produced by fracking jeopardizes species that live there, including threatened and endangered species that are already under great stress and important forage fish.

This is harmful specifically for this region, affecting the Estuary resources of Pennsylvania, New Jersey and Delaware, threatening all life in these zones of the Estuary and Bay. And since the tides carry pollutants, including increased salinity, upstream and into tributaries, areas that do provide drinking water (including the State of Delaware's tributary drinking water intakes, and Philadelphia and south Jersey drinking water intakes serving millions of people) and upstream river zones that are tidally influenced will all be negatively impacted to some degree. Risking the viability of species and water quality is a chance too great to take; the discharge of wastewater from fracking should be prohibited altogether.

Whole Effluent Toxicity (WET) testing is relied upon in DRBC's draft regulations as a method that will assure that effluent is not toxic. But WET testing is not a panacea. It should only be the first stage in a risk assessment; WET testing identifies a hazard(s), not how much risk is associated with that hazard. WET testing used to assess the effect of all pollutants in a facility's effluent is not conclusive.[ccv] DRBC should not rely on WET testing to predict toxic effects. As discussed earlier in this comment, many of the chemicals, including some with known adverse human health effects, used in fracking fluids do not have enough known about them to allow them to meet the requirements of EPA to be tested through a risk assessment and some are kept confidential as Trade Secrets. WET testing faces similar limits when chemicals are not disclosed or when the chemical's properties are not fully understood or known. This is a flawed approach that cannot be trusted when applied to frack wastewater, providing another reason why frack wastewater must be prohibited to prevent water resource damage.

It is unclear how treatment would be accomplished because DRBC does not propose treatment options. Discharging CWT wastewater to the surface waters of the Basin without causing significant contamination that threatens the drinking water and the Watershed's water resources throughout the Basin and without causing measurable negative change in the nontidal River, is not a viable option. This is especially true considering economic cost and partial administration of such a program. (Miller) Miller states:

> "Permissible treatment of the flowback and the produced water is not well defined. It is unclear how the post-treatment residual salts and radioactivity will be managed. There does not appear to be any complete treatment of these waters that will allow discharge of the water in any surface water of the Delaware River Basin.

In my opinion, there are no treatment options that can remove the contaminants in a cost effective manner, and suggest that until such a process is developed, discharge of HF water should simply be banned within the basin to avoid the unreasonable risk of the contamination and loss of drinking water resources. This is particularly the case for drinking water sources, but also for lower basin waters, primarily associated with ecological risk. Some of the membrane processes (e.g. reverse osmosis, nanofiltration) may meet the standards in some cases for a portion of the water, although the reject water will still need to be disposed out of the basin and will contain higher concentrations of all of the contaminants. Effectively, there is no reasonable cost alternative to simply transporting the HF waters to regions where deep well disposal is permitted, which is the way those waters are being managed to date.

The methods for treatment of the water for discharge to a surface water are not considered, and how specific requirements for discharge could be met by various treatment processes (e.g. membrane, ion exchange or evaporative processes) are not mentioned. The residual contaminants removed by evaporative or membrane processes, and thus concentrated to form even more contaminated water, were not discussed, other than to indicate that the residual salts, or concentrated brine will require "further treatment or disposal". For flowback or brine containing 7% (70,000 mg/L) salts, upwards of 300 tons of salts will exist in every million gallons of water, plus the concentrated NORM as well as a portion of the hydrocarbons. The source of the alpha emitters also will need to be identified. If, as is suspected, polonium is present in the flowback water, it represents an additional management burden of the flowback and produced water.

The best option is simply to prohibit storage or treatment of HF water in the Delaware River Basin entirely."[ccvi]

No federal standards have been issued to guide DRBC on the design and regulation of the treatment of wastewater produced by fracking. DRBC attempts to fill that void but fails to do so. The wastewaters produced by fracking are complex and variable, to the extreme of each truckload produced at a frack site varying from other truckloads due to the uncontrollable nature of the fluids injected and released by the deep geologic formations. Chemicals are injected by drillers that are protected as Trade Secrets and, in Pennsylvania we know this has prevented the disclosure of the contents of these fluids, which are also found in the wastewater or produced water that fracking generates.

These complexities and unknowns make the wastewater unpredictable while also being highly toxic and dangerous to human health and the environment. This is fundamentally different than other types of wastewater for which DRBC now issues dockets. It is not reasonable to expect any agency to perform the vigilance needed to handle this waste. The means of control are prohibition, to "remove the option of disposal". (Miller)

"I have examined many of the chemical and toxicological issues, particularly related to potential treatment and discharge into the Delaware River Basin of waters associated with hydraulic fracturing, primarily produced and flowback (formation) water. This issue has confronted the Delaware River Basin Commission for several years now, and

I appreciate the thought that has gone into these regulations. I feel strongly that, due to the chemical complexity of these highly contaminated waters, the best solution is to simply remove the option of disposal of any hydraulic fracture (HF) associated waters to any surface water in the Delaware Basin. The areas of the river designated by the Commission as Special Protection Waters (the nontidal river) cannot maintain adopted or proposed water quality standards nor meet the "No measurable change" requirement enforced by the Commission if the waters produced by hydraulic fracturing are discharged to the Basin's waterways, particularly if the HF waters are not treated to remove metals, salts and norm. The region below Philadelphia already receives a variety of discharges, and potentially adding a major load of a complicated array of contaminants from HF water should simply be prohibited."[ccvii]

The importation, treatment and discharge of produced water from fracking is contrary to the DRBC's stated goals of protection of water resources and the health of aquatic life and the public. The management challenges are not sufficiently met or assessed by the proposed regulations. (Parasiewicz) The methods of defining background concentrations for contaminants and the characterization of all contaminants in the wastewater stream are not developed or explained in the regulations. (Parasiewicz) Freshwater mussels such as the federally endangered dwarf wedgemussel are water filtering organisms that may be vulnerable to the toxic substances in CWT wastewater or produced water through long-term bioaccumulation but this is not addressed and must be. (Parasiewicz)

The cumulative impacts on species, habitats and water quality is not planned for but must be. The possible development of storage basins or tanks within the Watershed of highly toxic materials that cannot be sufficiently processed to meet discharge permit standards is not assessed or addressed in terms of management to avoid leaks, accidents, and spills of untreated produced water, concentrated residuals, or contaminated fluids and must be. (Parasiewicz)

It is documented in DRBC records that DRBC does already allow open lagoons and/or tanks within the Basin to temporarily hold materials too polluted to discharge into surface water due to conditions such as low flow; these dangerous materials that do not meet water quality standards for discharge are stored until they can be worked into the treatment system, risking accidental exposure to the environment and air emissions that could be harmful.

The obvious dangers of transport, accidental leaks and spills, and the inducement of development of HVHF in proximity to the Watershed by allowing the fracking-related activities of wastewater importation and water exportation, threatening additional impacts to the Basin, is not examined but must be. (Parasiewicz) Parasiewicz states:

> "Despite the requirement of alternatives analysis this proposition is also in contrast with the declaration of protection of public health and aquatic life, because:
>
> a. Many of the toxic substances occurring in the produced water of Marcellus Shale require special treatment with expensive technologies.
> b. Safe concentration of some of these substances (total dissolved solids, barium, bromide, radium and strontium) are not yet regulated and

treatability studies are still required even to characterize the pollutant loads in the produced water.

c. The long term bioaccumulation effects of these substances on biota is not well known. Water filtering organisms such as freshwater mussels may be particularly vulnerable to such toxic substances.

d. Similarly background concentrations that are required to be maintained according to the rule are yet to be determined.

e. Due to the fact that the produced water dissolves substances from target rock formation, it is conceivable that their concentration as well as their chemical composition may vary uncontrollably potentially exceeding the capacity of the treatment plant. Attempting to mitigate that would require toxic storage reservoirs with all associated and unacceptable risks of accidental breaching or leaching.

f. Transportation and handling of such substances is prone to accidental leaks, which are very difficult to control and account for.

g. It encourages the development of HVHF operations in the proximity of the Delaware Watershed with all the consequences described above."[ccviii]

Addressing what to do with all the waste produced by modern day fracking has been a formidable challenge. The trend in the increased volume of water used and, in turn, the increased volume of wastewater produced and discharged by fracking is making the challenge even more difficult. It has been consistently documented by agencies that unconventional wells (defined by geologic formation depth by PADEP; essentially these are shale gas wells that use HVHF) use more water than conventional wells (drilled into shallower depth rock formations as defined by PADEP), as illustrated by a comparison of waste generated in Pennsylvania. (FracTracker)

The number of conventional wells outnumber the unconventional wells by 3 to 1 in 2016-2017 but the cumulative volume of liquid waste produced by unconventional wells was more than 10 times than that of conventional wells. (FracTracker) Statistics from PADEP Oil and Gas Production Reports show the amounts in millions of barrels. (FracTracker Figure 4 and Tables 2 and 3) Solid waste in tons is also documented; 93% is disposed at landfills. (FracTracker, Table 4) Matt Kelso of FracTracker states:

> "Dealing with such large quantities of liquid waste has been problematic in Pennsylvania in recent years. Originally, much of this liquid O&G waste was treated in publicly owned treatment facilities, but due to rising contaminant levels in the rivers, the Pennsylvania DEP requested a voluntary cessation of the practice in April 2011, a move that was later made compulsory. However, other surface treatment facilities were not affected by this decision.
>
> Many other states rely heavily on oil and gas wastewater disposal wells to avoid surface treatment. This practice has created a number of problems as well, however, including aquifer contamination and induced seismic activity. In Pennsylvania, much of the geology has been deemed unsuitable for underground injection, although there are recent efforts to expand this program16 due to the immense volume of liquid waste now

being generated by the industry. In March 2018, the US Environmental Protection Agencies issued permits for two more of these disposal wells, including facilities in Allegheny and Elk counties. The industry does try to reuse some of this produced fluid, but there are limits to what they can do in that regard.

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

The Delaware River Basin already receives some waste generated by unconventional oil and gas wells in Pennsylvania. These facilities are located in Reading, Berks County; Hatfield, Montgomery County; and Myerstown, Lebanon County. (FracTracker) While the definitions of liquid and solid wastes are blurred due to the nature of these wastes that can vary from liquids, to sludge material, to loose solids, to dry cake, and the descriptive terminology is not consistent in reporting, it is important to document that some produced wastewater or solid waste is being handled and processed within the Basin now. (FracTracker, Figure 5 and Table 5.)

The pressure to dispose of waste from the rest of Pennsylvania is already occurring within the Basin and can be expected to expand if the draft regulations are adopted, providing the road map drillers need to find much needed new locations for disposal of the enormous volumes of waste being generated by fracking in the Commonwealth. Matt Kelso of FracTracker states:

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

The pressure to find locations for wastewater from fracking will grow as shale gas wells are drilled and fracked. The 45,000 wells that are forecasted to be drilled in the Interior Marcellus by 2045 will require even more water than prior projections expected due to the dramatic increase in the volume of water used per fracked well, as discussed earlier, and it will also translate into much larger volumes of wastewater (and solids) that must be disposed of. (FracTracker) "In an industry expecting to drill roughly 45,000 more wells just in the Interior Marcellus Formation of PA through 2045, the pressure to find new water sources and waste disposal sites will be ongoing in the coming decades, including within the Delaware River Basin. This will require over half a trillion gallons of water to stimulate, assuming that the per-well water consumption does not continue to increase beyond 2017 figures. If waste figures also hold steady, we will see 1.4 billion barrels (60 billion gallons) of toxic liquid waste and 28.5 million tons of solid waste that will need to be processed in the coming years."[ccxi] (FracTracker) Considering the advances in well boring technology and equipment, the volumes could reasonably be expected to increase to even greater levels. Matt Kelso of FracTracker states:

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

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

In an industry expecting to drill roughly 45,000 more wells just in the Interior Marcellus Formation of PA through 2045, the pressure to find new water sources and waste disposal sites will be ongoing in the coming decades, including within the Delaware River Basin. This will require over half a trillion gallons of water to stimulate, assuming that the per-well water consumption does not continue to increase beyond 2017 figures. If waste figures also hold steady, we will see 1.4 billion barrels (60 billion gallons) of toxic liquid waste and 28.5 million tons of solid waste that will need to be processed in the coming years. The actual figure is likely to be much more than that, however, as the current waste figures are based on the output of just 8,000 wells – if the industry drills 45,000 more, there will likely be times where there are tens of thousands of active unconventional wells generating immense volumes of waste simultaneously.

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

Comment on Proposed Revision to Section 18 CFR 401.35(a) and (b) Classification of projects for review under Section 3.8 of the Compact

Section 401.35 (a) currently reads: "Except as the 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:"

Section 18 CFR 401.35(a) (15)

DRN recommends changes to the proposed text at Section 18 CFR 401.35(a) (15) which reads: "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 where neither state nor a federal level review and permit system is in effect".

DRN recommends: “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, shall be subject to Commission review and action”.

DRN considers DRBC to have more local and immediate information, data, and knowledge of wetlands that the state or federal agencies. Even though DRBC does not currently have detailed maps of all wetlands within the Basin, this research can be carried out more thoroughly under DRBC than under the more distant agencies that have less data and local knowledge on wetlands and marshes within the Basin. DRN considers DRBC to have 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.

DRN does not consider the 25 acre threshold for review that is currently in place and used as a threshold in the Draft Regulations to be scientifically-based. There is no justification that DRBC has produced to support the arbitrary threshold of 25 acres. DRN objects to 25 acres being used as a threshold for substantial impact.

Wetlands are located throughout the Delaware River Watershed and constitute a critical natural feature and a keystone ecosystem. Wetlands are sensitive to development activities and are documented to have been degraded by oil and gas development. Thorough and comprehensive oversight and review of all disturbance of wetlands and marshes is required to provide needed protection for the integrity of these ecosystems and the water resources of the Basin.

Miller states that "Wetlands are among the most threatened ecosystems on the planet. They are degraded and converted to human uses more rapidly than any other ecosystem, and the status of freshwater species is deteriorating faster than any other species. Since wetlands are essentially characterized by hydrologic conditions, changes in water volumes and timing of flows are major threats, as are discharges of various pollutants."[ccxiii]

Section 18 CFR 401.35(a) (18)

DRN recommends a change in the text at Section 18 CFR 401.35(a) (18) which is proposed in the Draft Regulations as: "Except as provided at 18 CFR401.35(b) (18), the diversion or transfer of wastewater into the Delaware River basin (importation) whenever the design capacity is less than a daily average of 50,000 gallons".

DRN recommends the text be changed to read: "Except as provided at 18 CFR401.35(b) (18), the diversion or transfer of wastewater into the Delaware River Basin (importation)".

DRBC has more information about the potential impacts of wastewater, excluding wastewater produced by fracking which must be wholly prohibited, on the resources of the Basin and can potentially provide better oversight and review than the host state from where the wastewater is originating. For the myriad of reasons discussed in this Comment, the water resources of the basin are at risk of degradation by toxic discharges and should be under the jurisdiction of the DRBC no matter the volume of the wastewater.

Section 18 CFR 401.35(a) (19)

DRN recommends a change in the text at Section 18 CFR 401.35(a) (19) which is proposed in the Draft Regulations as: “To the extent allowed in the basin (see prohibition at 18 CFR440.3(b)), projects involving hydraulic fracturing, unless no state-level review and permit system is in effect;”.

DRN recommends Section 18 CFR 401.35(a) (19) be deleted and that NO hydraulic fracturing be allowed within the Basin, regardless of the state-level review and permit system that is in effect.

Considering the reasons provided in this Comment, DRN opposes all drilling and fracking for gas and oil within the Delaware River Basin.

Section 401.35 (b) currently reads: “All other projects which have or may have a substantial effect on the water resources of the basin shale 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) of this section:”

Section 18 CFR 401.35(b) (14)

DRN recommends changes to Section 18 CFR 401.35(b) (14) that is proposed in Draft Regulations as: “Leachate treatment and disposal projects associated with landfills and solid waste disposal facilities in the basin”.

DRN recommends the text be changed 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”.

DRN agrees that leachate associated with landfills and solid waste facilities must be included in this Section because of the potential for substantial effect on the water resources of the Basin. DRN recommends the above text change based on the fact that toxic and radioactive waste generated by fracking is currently being imported to the basin, as discussed in this Comment, so it is a known threat but DRBC may not have any knowledge of this ongoing activity. DRBC cannot effectively carry out its responsibilities or implement its regulations that protect the water resources of the Basin unless it has information about the importation of wastes from fracking.

Landfills and solid waste disposal facilities are likely to continue to receive waste generated by fracking and drilling as gas development continues in the hydrocarbon bearing rock formations in the host sates and beyond. We know, as discussed in this Comment, that landfill radioactivity monitors have been set off hundreds of times by drilling and fracking waste; there is no change in the radioactive properties of waste generated by fracking that has changed or can reasonably be expected to change. Therefore, the threat of radioactive and toxic materials generated by fracking will remain, requiring DRBC to have review and regulatory authority over these activities. Based on the information contained in this Comment, DRN recommends that all fracking-related waste materials be prohibited from importation, storage, processing, treatment, disposal, and discharge within the Delaware River Basin.

II. INTERSTATE COMMERCE CLAUSE DOES NOT PREVENT A BAN ON IMPORTATION, STORAGE, PROCESSING, AND DISCHARGE OF OIL AND GAS WASTEWATER

The Interstate Commerce Clause of the United States Constitution **does not** prevent the Delaware River Basin Commission ("DRBC") from imposing a ban on the importation, storage, processing and discharge of oil and gas wastewater in the Basin. The ban would not prohibit transportation of wastewater through the Basin.

a. DRBC's Current and Proposed Oversight of Oil and Gas Wastewater

The DRBC has described its current oversight of oil and gas wastewater as follows:

> In some but not all cases, DRBC docket approvals for wastewater discharges include a condition expressly providing that the docket does not constitute an approval to import wastewater from ***hydraulic fracturing activities***, and stating that if the docket holder proposes to import and treat such wastewater, it must first apply for and obtain Commission approval for this activity. Such docket conditions do not constitute a moratorium.

DRBC, FAQ - Revised Draft Rules Addressing Hydraulic Fracturing Activities within the Delaware River Basin, at p.6 (emph. added). The DRBC has proposed new regulations that would "require Commission approval for the importation into the Basin and treatment and discharge within the Basin of wastewater from hydraulically fractured oil and gas wells." Id. at p.1.

The proposed rules would address more than simply fracking wastewater. The proposed rules deal with "produced water" and "CWT wastewater." "Produced water" is very broad:

> 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.

"CWT wastewater" is "any wastewater or effluent resulting from the treatment of produced water by a CWT [centralized waste treatment facility, as defined in the proposed regulations]."

Thus, the DRBC proposes to address more than fracking wastewater, potentially affecting all oil and gas wells. At the present time, according to available data, there are almost no oil and gas wells in New York or Pennsylvania in the Basin area – unconventional or conventional.

b. Standards and Analysis

The Interstate Commerce Clause and the "Dormant Commerce Clause"

Article I, sec. 8, cl. 3 of the United States Constitution is what is known as the Interstate Commerce Clause. It states, "[The Congress shall have Power] To regulate Commerce with foreign Nations, and among the several States, and with the Indian Tribes." Case law has developed over time to address what is known as the Dormant Commerce Clause ("DCC"), which is an implied reading of the Interstate Commerce Clause designed to prevent states from erecting barriers to or otherwise interfering with interstate commerce. "[T]he Commerce Clause is designed to eliminate protectionist restrictions on interstate trade which typically characterize international trade, such as embargoes, quotas, and tariffs." *Norfolk Southern Corp. v. Oberly*, 822 F.2d 388, 399 (3d Cir. 1987). Such state-versus-state provisions were common prior to the U.S. Constitution, during the period in which the Articles of Confederation governed. Id. A simple example of a protectionist restriction is a tariff that applies solely to out-of-state goods. "The Supreme Court has recognized a . . . Commerce Clause interest in federal uniformity in cases addressing state regulation of the means of interstate transportation." Id.

The DCC was central to a number of "flow control" challenges, in which states such as New Jersey had enacted bans on importation of out-of-state waste in order to preserve in-state landfill space for in-state waste. *See, e.g., Phila. v. N.J.*, 437 U.S. 617 (1978). Such preferential treatment for in-state waste was deemed discriminatory; however, the Court of Appeals left open the option that the state could have enacted other regulations to preserve landfill space that treated in-state and out-of-state waste alike. *Norfolk Southern Corp.*, 822 F.2d at 401.

In other cases, environmental regulations blocking the importation of certain out-of-state goods have been upheld where the state was able to specifically identify with scientific evidence reasons why importation of certain goods (i.e. live baitfish) posed a threat that the state could only truly address through a ban on the out-of-state goods. Maine v. Taylor, 477 U.S. 131 (1986).

The U.S. Court of Appeals for the Third Circuit has explained:

> In general terms, the Supreme Court has invalidated under the dormant Commerce Clause state laws falling into three categories: 1) laws that purposefully or arbitrarily discriminate against interstate commerce in favor of in-state interests . . . ; 2) laws that

> impose incidental burdens on interstate and foreign commerce that are clearly excessive in comparison to the putative local benefits . . . ; and 3) laws that undermine the federal need for uniformity among the states in particular areas, such as foreign trade and interstate transportation.

Norfolk Southern Corp., 822 F.2d at 398.

The DCC case law is often inconsistent. At times, the line between an improper regulation and a valid one is fuzzy, particularly when determining whether a law's discriminatory effects are such that it discriminates against out-of-state entities, or whether it merely incidentally burdens interstate commerce, and thus a lower standard of scrutiny would apply.

The Third Circuit summarized three categories of cases and thus varying levels of scrutiny to apply to challenges to state regulations that purportedly affect or impair interstate commerce.

> Three standards of review are applied in performing dormant Commerce Clause analysis: 1) state actions that purposefully or arbitrarily discriminate against interstate commerce or undermine uniformity in areas of particular federal importance are given heightened scrutiny; 2) legislation in areas of peculiarly strong state interest is subject to very deferential review; and 3) the remaining cases are governed by a balancing rule, under which state law is invalid only if the incidental burden on interstate commerce is clearly excessive in relation to the putative local benefits.

Id. at 398-99.

For Category 1 cases, "Discrimination against interstate commerce in favor of local business or investment is *per se* invalid, save in a narrow class of cases in which the municipality can demonstrate, under rigorous scrutiny, that it has no other means to advance a legitimate local interest." *C & A Carbone, Inc. v. Town of Clarkstown, NY*, 511 U.S. 383, 393 (1994)(citing *Maine v. Taylor*, 477 U.S. 131 (1986)).

Category 1-type cases are those like *Phila. v. N.J.* and *Maine v. Taylor*, in which there is a difference in treatment – whether facially or in effect – between in-state and out-of-state entities. The standard explained in Category 2 does not apply to "nondiscriminatory environmental statutes." *Norfolk Southern Corp.*, 822 F.2d at 398, 405.

Category 3 cases involve statutes that treat in-state and out-of-state entities alike, but still impose some burden on interstate commerce. For example, in *Norfolk Southern Corp.*, the Third Circuit upheld Delaware's ban on new industrial activity in the coastal zone. It found no difference in burden between in-state and out-of-state entities as far as being restricted from building in the coastal zone, and no burden that was excessive; this obviated the need to review the state's conclusion that industrial activity of the type proposed would endanger the coastal zone through pollution. *Norfolk Southern Corp.*, 822 F.2d at 406-07; *see also Huron Portland Cement, Inc. v. Detroit*, 362 U.S. 440 (1960). In contrast, the U.S. Supreme Court invalidated a state law pertaining to fruit packaging that would have required an in-state entity to invest a substantial amount of money to build an in-state packing facility, rather than continuing to ship its melons to another state for packing. *Pike v. Bruce Church, Inc.*, 397 U.S. 137 (1970). It found this burden to be excessive in comparison to the state interest, which was "to protect and enhance the reputation of growers within the State." Id. at 143.

The Dormant Commerce Clause Case Law Does Not Apply to the DRBC

The DCC does not apply to the DRBC because the DRBC is an interstate entity. Courts have repeatedly found that construction of an interstate compact is a question of federal law, not state law, and that compacts are to be construed in the same manner as contracts. *Tarrant Reg'l Water Dist. v. Hermann*, 569 U.S. 614, 628 (2013); *Texas v. New Mexico*, 482 U.S. 124, 128, (1987); *Cuyler v. Adams*, 449 U.S. 433, 438 (1981); *Petty v. Tenn.-Missouri Bridge Comm'n*, 359 U.S. 275, 278-79 (1959). The DRBC also has, as one of its members, the federal government, and Section 2.1 of the Compact specifically identifies the DRBC as "an agency and instrumentality of the governments of the respective signatory parties," including the federal government. Thus, the Dormant Commerce Clause should not apply at all because there is no state entity here – it is an interstate or federal agency exercising powers beyond the boundaries of any one state.

c. Even if the Dormant Commerce Clause Applies to DRBC Actions, It Only Applies When Those Actions Are Based on State Boundaries, not Basin Boundaries

Industry may attempt to argue that the Dormant Commerce Clause applies by pointing to Section 1.4 of the Compact, which states:

> Nothing in this compact shall be construed to relinquish the functions, powers or duties of the Congress of the United States with respect to the control of any navigable waters within the basin, ***nor shall any provision hereof be construed in derogation of any of the constitutional powers of the Congress to regulate commerce among the states*** and with foreign nations.

(emph. added); *see also* Section 15.1(s), (t). Thus, although the Compact itself is federal law, and the federal government is a member, there is also a provision stating that the Interstate Commerce Clause still has some impact on the DRBC. However, we have not yet found a case challenging an interstate agency's exercise of authority on the basis of the Dormant Commerce Clause to determine precisely what that impact would be. Practically, the federal government's interest in and authority over the free flow of interstate commerce is protected in part by its membership on the DRBC. *Cf. W.Va. ex rel. Dyer v. Sims*, 341 U.S. 22, 26-28 (1951) (discussing the Ohio River Valley Water Sanitation Compact and that the "national interest" was safeguarded both by Congressional consent under the Compact Clause, and by the federal government's membership in the compact agency); *see also Cuyler*, 449 U.S. at 438 (Congressional consent under the Compact Clause allows Congress to "maintain ultimate supervisory power over cooperative state action that might otherwise interfere with the full and free exercise of federal authority").

One way to read Section 1.4 is that it provides a backstop against a majority vote of the DRBC to engage in specific actions that would interfere with or impair interstate commerce across state lines in the same fashion that state regulation is not allowed to do. For instance, if the DRBC voted to prohibit the importation of waste into New Jersey from the Pennsylvania portion of the Basin, this would be very similar to the fact pattern in *Phila. v. N.J.*, 437 U.S. 617 (1978), and would likely be found improper. Given the contentious history of water allocation between DRBC signatory states, it is possible that preventing discrimination against particular states (commerce across state boundaries, rather than basin boundaries) is one reason for the provision – to provide one more check against abuse of authority to benefit or harm certain signatory states over others.

If that is the case, that concern does not arise in regard to a ban on the importation of fracking wastewater into the Basin because it would not result in discrimination on the basis of state borders. While it is true that Pennsylvania currently has the most shale gas activity, the proposed regulation does not distinguish between shale gas and other wells. Likewise, a proposed regulation applies to brines, which can come from any type of oil or gas well regardless of whether shale gas development is allowed in the state or not. The proposed regulations are, on their face, concerned with watershed boundaries, not state boundaries. Viewed in this light, it is clear that the proposed regulations would not discriminate on the basis of state boundaries. As a result, the Category 3 standards from *Pike v. Bruce Church, Inc.* would apply, and the analysis would revolve around whether the incidental burden on commerce across signatory state lines in the Basin is clearly excessive relative to the local benefits from the wastewater ban. *Norfolk Southern Corp.*, 822 F.2d at 398-99.

As will be discussed further below, there is significant scientific evidence to support the harms associated with improperly treated produced water and CWT wastewater, and the difficulty of achieving proper treatment that justify the prohibition on bringing these types of wastewater into the Basin, including across signatory state lines. As for the incidental burden, wastewater from oil and gas operations already has to be shipped long distances because facilities capable of handling the wastewater are limited in number. Thus, prohibiting wastewater from coming into the Basin and across signatory state lines does not carry with it the same weight if the wastewater were more easily treatable in closer distances. Also, the sparse history of oil and gas development in the Basin means a far less likely chance that anyone would even need to send wastewater into the Basin and across signatory state lines for storage, processing, treatment and discharge due to the lack of facilities.

Industry may go further to claim that the Compact language in Section 1.4 is designed to avoid in-Basin/out-of-Basin discrimination that impacts interstate commerce, as if the DRBC were itself a state, and the boundaries of the Basin were equivalent to state borders. This perspective would favor application of DCC case law to the DRBC in a way that recognizes DRBC as an interstate entity whose actions could be construed as impeding commerce flow across Basin borders. Even assuming, arguendo, that this view of Section 1.4 prevailed, it would not change the result, as explained further below.

d. Even if the Ban on Importation Based on Basin Boundaries Is Viewed as the Equivalent of a Ban that is Based on State Boundaries, It Would Still Survive Challenge

Below we apply the Category 1 and Category 3 standards to a potential DRBC oil and gas wastewater ban. For the purposes of this analysis, we assume a potential industry view that would equate "in-Basin" and "out-of-Basin" to "in-state" and "out-of-state" to apply the relevant case law.

<u>Category 1: Differential Treatment Between In-Basin and Out-of-Basin Entities/Blocking Commerce Flow at Basin Borders and Heightened Scrutiny</u>

When a regulation discriminates against interstate commerce (either on its face or through its effects), the burden is on the "State to demonstrate both that the statute 'serves a legitimate local purpose,' and that this purpose could not be served as well by available nondiscriminatory means." *Maine*, 477 U.S. at 138 (quoting *Hughes v. Okla.*, 441 U.S. 322, 336 (1979). It could theoretically be argued that a ban on importation of produced water and CWT wastewater into the Basin while placing no restrictions on in-Basin produced water and CWT wastewater would trigger this level of heightened scrutiny because it facially discriminates against out-of-Basin-generated produced water and CWT wastewater.

Assuming that there is no storage, processing, treatment, and discharge of in-basin-generated produced water or CWT wastewater, the DRBC could argue that there is no discriminatory treatment because no such in-Basin activities, posing the same threats, are occurring while the out-of-Basin entities are barred from doing so (and thus, there can be no discrimination between in-Basin and out-of-Basin occurring). *Norfolk Southern Corp.*, 822 F.2d at 401-02; *Exxon Corp. v. Md.*, 437 U.S. 117, 125 (1978).

Even if the ban were to trigger the highest level of scrutiny, a DRBC ban should survive heightened scrutiny. Although heightened scrutiny has invalidated many laws, the DRBC ban situation can be distinguished from *Phila. v. N.J.*, and analogized to *Maine v. Taylor*, a case in which the local law was upheld.

First, the ban serves a "legitimate local purpose" in protecting Basin waters and the uses that rely on those waters from the well-documented impacts of poorly-treated oil and gas wastewater. Science has strongly established the harms associated with inadequately-treated oil and gas wastewater in Pennsylvania streams and rivers. This includes streams whose sediments are now radioactive due to the discharges from certain centralized waste treatment facilities, and streams whose ecology was turned to that of a saltwater environment. Inadequately-treated oil and gas wastewater can negatively affect public drinking water supplies, in addition to harming aquatic life and changing the salinity of the aquatic environment. Protecting Basin water resources from the threat of produced water and CWT wastewater based on this science demonstrates that there is a legitimate local interest at play. In comparison, in Maine, state experts "testified that live baitfish imported into the State posed" threats of parasites and nonnative species to Maine's wild fish and aquatic ecology, which the Court found to meet the legitimate local interest requirement. 477 U.S. at 140-41.

Second, even if one concluded that there was discrimination, protecting Basin waters and the uses they support would not be "served as well by available nondiscriminatory means." *Maine*, 477 U.S. at 138. Although the DRBC proposed regulations seem to suggest that the DRBC thinks such means exist, the science says otherwise. For example, full disclosure of all potential pollutants requiring treatment in produced water and CWT wastewater is impossible when fracking has been employed because the industry uses undisclosed "trade secret" constituents that will be present in the wastewater. This hampers proper treatment of the wastewater, exposing Basin waters, users, and the aquatic ecology to significant uncertainties and risks. *Cf. Maine*, 477 U.S. at 148 ("Maine has a legitimate interest in guarding against imperfectly understood environmental risks, despite the possibility that they may ultimately prove to be negligible").[3]

[3] *See also id.* quoting the District Court's opinion in 585 F.Supp. 393, 397 (D.Mn. 1984) ("[T]he constitutional principles underlying the commerce clause cannot be read as requiring the State of Maine to sit idly by and wait until potentially irreversible environmental damage has occurred or until the scientific

If industry were to argue that there should be an allowance of some oil and gas wastewater (e.g. wastewater with fracking fluids in it versus others), there is no easy way to distinguish different types of oil and gas wastewater from one another except via sampling every load and determining if it should be allowed into the Basin. *Cf. Maine*, 477 U.S. at 141-42 (state experts testified to "no satisfactory way to inspect shipments of live baitfish for parasites or commingled species," that it would be a "physical impossibility," and that "no scientifically accepted procedures" for certifying a shipment as parasite-free "were [not] available for baitfish."). That is a high administrative burden that the DRBC need not take on to protect the waters of the Basin from a known threat. *Cf. id.* at 147 (state not required to "develop new and unproven means of protection at uncertain cost").[4]

Category 3: Nondiscriminatory Environmental Standards and a Balancing Test

For Category 3 cases, "the extent of the burden that will be tolerated will . . . depend on the nature of the local interest involved, and on whether it could be promoted as well with a lesser impact on interstate activities." *Pike v. Bruce Church, Inc.*, 397 U.S. 137, 142 (1970). Because a ban can pass the stricter standard set forth above, it can pass the balancing test as well. The same evidence described above would be useful to defend the ban under this standard.

community agrees on what disease organisms are or are not dangerous before it acts to avoid such consequences.")

[4] In practice, a significant amount of wastewater goes to places capable of deep injection, such as Ohio, thus, wastewater generators and transporters already have a substantial burden to bear as far as transport in comparison to what the DRBC would be doing.

e. Applying the Standards to a Potential Ban If In-Basin Produced Water and CWT Wastewater Storage, Processing, Treatment, and Discharge Exists

This analysis assumes that there is no produced water or CWT wastewater being generated, processed, treated, stored, and discharged in the Basin currently. A stronger approach that would account for any such in-Basin activities that might exist or that might begin in the future would be for the DRBC to ban processing, storage, treatment and discharge of produced water and CWT wastewater *regardless of origin*, whether in-Basin or out-of-Basin. Such an approach would avoid the pitfall inherent in New Jersey's trash importation ban, which "impose[d] on out-of-state commercial interests the full burden of conserving the State's remaining landfill space." 437 U.S. at 628.

To further strengthen this approach, we recommend that the DRBC include in the definition of "produced water" the liquid fraction of otherwise-solid waste, such as drill cuttings. For instance, some loads of drill cuttings that arrive at waste facilities are highly saturated with oils and other fluids. That liquid fraction can separate out and remain in the bottom of the waste container, requiring the receiving facility to do something with that waste fluid. That waste fluid may contain brine-type material, radioactive materials, drilling mud, or other chemical constituents that need proper treatment. Other facilities may bring in wastewater, separate out the solids in the wastewater for disposal in a landfill, and return the wastewater to the operator. The DRBC's current regulations do not account for this liquid waste or these types of scenarios, even though these activities pose threats to the health of

Basin waterways that are similar to the threats posed by the other oil and gas wastewater the DRBC is proposing to regulate.

If the DRBC took the approach of banning activities regardless of the wastewater's origin, the mere fact that the majority of oil and gas wastewater would come from outside of the Basin would likely not change the fact that both in-Basin and out-of-Basin entities were subject to the same standards. 822 F.2d at 402; *Exxon Corp. v. Md.*, 437 U.S. 117, 125 (1978).[5] Such an across-the-board ban would support the conclusion that the ban is based on environmental protection, in contrast to economic protectionism. *Cf. id.* at 403-04. A ban that treated in-Basin and out-of-Basin entities alike would be subject to the Category 3 standard, under which "state law is invalid only if the incidental burden on interstate commerce is clearly excessive in relation to the putative local benefits." *Id.* at 398-399. As already noted, the available science and knowledge of how difficult oil and gas wastewater is to treat – regardless of fracking fluid presence or not – would support the immense local benefits to keeping such wastewater out of Basin water resources. Also, it is common for oil and gas wastewater to be transported long distances to facilities for treatment. This differs from *Pike v. Bruce Church, Inc.*, in which the local benefits of melon packaging were far

---

[5] Although the DRBC could take the route of including a grandfather clause for facilities currently accepting to-be-prohibited waste streams, which would not affect the Commerce Clause analysis, the need for such a clause is not apparent because any facilities currently accepting waste do not appear to be solely dependent on oil and gas waste fluids and wastewater for their business. *Norfolk Southern Corp.*, 822 F.2d at 404. Thus, banning certain waste streams would not result in the facility shutting down, lowering the risk of a regulatory takings claim that might otherwise warrant a grandfathering clause.

less than the burden on a company to invest thousands of dollars to build an in-state packaging plant.

Conclusion

Delaware Riverkeeper Network supports DRBC's proposal for the prohibition of high volume hydraulic fracturing (HVHF) in hydrocarbon bearing rock formations within the Delaware River Basin ("the Basin"). DRN opposes the diversion, transfer or exportation of water from sources within the Basin of surface water, groundwater, treated wastewater or mine drainage water for utilization in hydraulic fracturing ("fracking") of hydrocarbon carbon bearing rock formations outside the Basin as proposed at Section 440.4. DRN opposes the importation, transfer, treatment, storage, disposal, or discharge in the Basin of produced water and Centralized Waste Treatment (CWT) wastewater generated by fracking operations, as proposed at Section 440.5. DRN requests the DRBC remove all reference to the allowance of water exports from the Basin for fracking and the import and storage, processing, disposal and discharge of CWT wastewater and produced water from fracking in the Basin, as described at Sections 440.4 and 440.5. DRN also requests that Section 440.3(b) is expanded to include prohibition of the activities related to fracking, specifically including the export of water and water resources out of the Basin for fracking elsewhere and the prohibition of the importation, transfer, treatment, storage, disposal, or discharge in the Basin of produced water and Centralized Waste Treatment (CWT) wastewater generated by fracking operations.

Respectfully submitted this 30th day of March 2018,

Maya K. van Rossum
the Delaware Riverkeeper
keepermaya@delawareriverkeeper.org

Tracy Carluccio
Deputy Director
Delaware Riverkeeper Network
tracy@delawareriverkeeper.org

/s/ Aaron Stemplewicz
Aaron Stemplewicz
Delaware Riverkeeper Network
925 Canal Street, Suite 3701
Bristol, PA 19107
Phone: 215.369.1188
Fax: 215.369.1181
aaron@delawareriverkeeper.org
Counsel for: *Petitioners Delaware Riverkeeper Network and the Delaware* March 28, 2018

Attachments:

Attachment 1: Expert reports

1. Tom Myers, "Technical Memorandum: Review of Proposed Natural Gas Regulations as Proposed by the Delaware River Basin Commission", March 12, 2018

2. Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018

3. FracTracker Alliance, “Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin”, March 20, 2018

4. Schmid & Company, Inc., “Comments on Proposed Regulations of the Delaware River Basin Commission Concerning High Volume Hydraulic Fracturing to Produce Oil and Gas, 3.18.2018

5. Piotr Parasiewicz, PhD, A.Prof., “Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities,” February 2018

6. Marvin Resnikoff, “Memorandum, DRBC Draft Regulation Comments”, Radioactive Waste Management Associates, February 19, 2018

Attachment 2: Curriculum Vitae for Experts

1. Kunz (Schmid and Co.)

2. Schmid

3. Parasiewicz

4. Resnikoff

5. Kelso (FracTracker)

6. Myers

7. Miller

---

[i] Michele Adams, “Unsafe and Unsustainable,” Delaware Riverkeeper Network, 2014, p. 15-16 http://www.delawareriverkeeper.org/Documents/DRN_Report_Unsafe+Unsustainable_fr.pdf

[ii] Hanson, L., Habicht, S., Daggupati, P., Srinivasan, R., & Faeth, P. (2017). Modeling changes to streamflow, sediment, and nutrient loading from land use changes due to potential natural gas development. *Journal of the American Water Resources Association*, Vol.53, No. 6, 1293 – 1312. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12588

[iii] Michele Adams, “Unsafe and Unsustainable,” Delaware Riverkeeper Network, p. 15-16, 2014, http://www.delawareriverkeeper.org/Documents/DRN_Report_Unsafe+Unsustainable_fr.pdf page 10.

[iv] Evans, Kiesecker, “Shale Gas, Wind, and Water: Assessing the Potential Cumulative Impacts of Energy Development on Ecosystem Services within the Marcellus Play”, PLOS/One, DOI: 10.1371/journal.pone.0089210, February 19, 2014.

[v] Ibid.

[vi] Gerald J. Kauffman, Socioeconomic Value of the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania”, University of Delaware, 10.11.11, p. 26.

[vii] Kiviat, E., & Schneller-McDonald, K. (2011). Fracking and Biodiversity: Unaddressed Issues in the New York Debate. *News from Hudsonia*, Vol. 25, No. 1 & 2. Retrieved from http://hudsonia.org/wp-content/uploads/2012/01/nfh-Fracking-biodiversity-best.pdf
[viii] Ibid.
[ix] Ibid.
[x] Robert A. Smail & David J. Lewis, Forest Service, U.S. Dep't of Agric., Forest Land Conversion, Ecosystem Services, and Economic Issues for Policy: A Review 12 (2009), www.fs.fed.us/openspace/fote/pnw-gtr797.pdf
[xi] Jackson, J.K. & Sweeney, B.W., "Expert Report on the Relationship Between Land Use and Stream Condition (as Measured by Water Chemistry and Aquatic Macroinvertebrates) in the Delaware River Basin," Stroud Water Research Center, Avondale, PA.
[xii] Hutson, S.S., Linsey, K.S., Ludlow, R.A., Reyes, Betzaida, and Shourds, J.L., 2016, Estimated use of water in the Delaware River Basin in Delaware, New Jersey, New York, And Pennsylvania, 2010: U.S. Geological Survey Scientific Investigations Report 2015–5142, 76 p., http://dx.doi.org/10.3133/sir20155142, Table 1, Introduction, p. 4.
[xiii] Academy of Natural Sciences of Drexel University, "A Preliminary Study of the Impact of Marcellus Shale Drilling on Headwater Streams," available at http://www.ansp.org/research/pcer/projects/marcellus-shale-prelim/index.php
[xiv] Olmstead, et.al. "Shale gas development impacts on surface water quality in Pennsylvania", Proc Natl Acad Sci U S A. 2013 Mar 26; 110(13): 4962–4967. Published online 2013 Mar 11. Doi: 10.1073/pnas.1213871110, PMCID: PMC3612605 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3612605/
[xv] Entreken, S.A., Maloney, K.O., Kapo, K.E., Walters, A.W., Evans-White, M.A., & Klemow, K.M. (2015). Stream Vulnerability to Widespread and Emergent Stressors: A Focus on Unconventional Oil and Gas. *PLoS ONE* 10(9): e0137416. Retrieved from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0137416
[xvi] Ibid.
[xvii] Ibid.
[xviii] Ibid.
[xix] Ibid.
[xx] Schmid & Company, Inc., "Comments on Proposed Regulations of the Delaware River Basin Commission Concerning High Volume Hydraulic Fracturing to Produce Oil and Gas, 3.18.2018, p. 12.
[xxi] Ibid. p. 11
[xxii] Kiviat, E., & Schneller-McDonald, K. (2011). Fracking and Biodiversity: Unaddressed Issues in the New York Debate. *News from Hudsonia*, Vol. 25, No. 1 & 2. Retrieved from http://hudsonia.org/wp-content/uploads/2012/01/nfh-Fracking-biodiversity-best.pdf
[xxiii] Kiviat, E., & Schneller-McDonald, K. (2011). Fracking and Biodiversity: Unaddressed Issues in the New York Debate. *News from Hudsonia*, Vol. 25, No. 1 & 2. Retrieved from http://hudsonia.org/wp-content/uploads/2012/01/nfh-Fracking-biodiversity-best.pdf
[xxiv] http://www.state.nj.us/dep/dsr/wetlands/final.pdf
[xxv] New Hampshire Office of Energy and Planning, "Wetlands Mitigation/Restoration Issues", Technical Bulletin 2, spring 1988.
[xxvi] http://www.gpo.gov/fdsys/granule/CFR-2012-title40-vol34/CFR-2012-title40-vol34-sec1508-20/content-detail.html
[xxvii]http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023
[xxviii] http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023 AND http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023
[xxix] Ibid.
[xxx] Ibid.
[xxxi] Tom Myers, "Technical Memorandum: Review of Proposed Natural Gas Regulations as Proposed by the Delaware River Basin Commission", March 12, 2018, p.1.
[xxxii] Ibid. p. 3.
[xxxiii] Ibid. p. 3.
[xxxiv] Ibid. p. 2.
[xxxv] Ibid. p. 4.
[xxxvi] Kiviat, E., & Schneller-McDonald, K. (2011). Fracking and Biodiversity: Unaddressed Issues in the New York Debate. *News from Hudsonia*, Vol. 25, No. 1 & 2. Retrieved from http://hudsonia.org/wp-content/uploads/2012/01/nfh-Fracking-biodiversity-best.pdf
[xxxvii] Tom Myers, "Technical Memorandum: Review of Proposed Natural Gas Regulations as Proposed by the Delaware River Basin Commission", March 12, 2018, p.5-6.
[xxxviii] Ibid. p. 6.
[xxxix] Ibid. p. 7-8.

[xl] Ibid. p. 9.
[xli] Ibid. p. 9-10.
[xlii] Ibid. p. 10-11.
[xliii] Ibid. p. 12-13.
[xliv] Ibid. p. 13.
[xlv] Paul Rubin, Report for the Delaware River Basin Commission on Natural Gas Development Regulations December 9, 2010, Article 7 of Part III – Basin Regulations, 2011, p. 3-4.
[xlvi] Paul Rubin, Report for the Delaware River Basin Commission on Natural Gas Development Regulations December 9, 2010, Article 7 of Part III – Basin Regulations, 2011, p. 10-29.
[xlvii] Ibid.
[xlviii] Rubin, Paul, 2014. "Unsafe and Unsustainable", Delaware Riverkeeper Network, p. 27.
[xlix] Rubin, Paul, 2014. "Unsafe and Unsustainable", Delaware Riverkeeper Network, p. 36, 38 and 39.
[l] Ibid.
[li] https://www.skytruth.org/about/ "SkyTruth uses the view from space to motivate people to protect the environment. We utilize technology to identify and monitor threats to the planet's natural resources such as offshore drilling and oil spills, urban sprawl, fracking, mountaintop removal mining, and overfishing of the oceans." Accessed 3.28.18.
[lii] Personal communication with excel sheet attachment, Dan Cogswell daniel.cogswell@skytruth.org to Tracy Carluccio, tracy@delawareriverkeeper.org, Fri 3/23/2018 5:32 PM.
[liii] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (5th ed.). http://concernedhealthny.org/compendium/
[liv] psr.org/resources/fracking-compendium.html, p. 266.
[lv] Hays, J. & Shonkoff, S.B.C. (2016). Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer- Reviewed Scientific Literature, 2009-2015. *PLoS ONE*, Vol. 11, No.4. Retrieved from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154164
[lvi] Ibid.
[lvii] Ibid.
[lviii] Ibid.
[lix] Ibid.
[lx] http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Determination_Letters/Regional_Determination_Letters.pdf
[lxi] http://www.nationofchange.org/2017/01/31/9442-citizen-reported-fracking-complaints-reveal-12-years-suppressed-data/
[lxii] https://stateimpact.npr.org/pennsylvania/2017/01/31/data-trove-offers-new-details-on-complaints-to-dep-during-shale-boom/ and https://docs.google.com/spreadsheets/d/1_tg1zTCA-xTmFk4erdcYJt4zqmQZ9x89qliQg55zekg/edit#gid=1060152199 and https://maps.fractracker.org/latest/?appid=f973714e27c14e1ebee222d2560f8cb0
[lxiii] http://publicherald.org/hidden-data-suggests-fracking-created-widespread-systemic-impact-in-pennsylvania/
[lxiv] USEPA (U.S. Environmental Protection Agency). 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Office of Research and Development, Washington, DC. EPA-600-R-16-236Fa. Available at: www.epa.gov/hfstudy; Hein 2012, p. 2. https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990
[lxv] https://www.epa.gov/sites/production/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf
[lxvi] Betanzo, E.A., Hagen, E.R., Wilson, J.T., Reckhow, K.H., Hayes, L., Argue, D.M., and Cangelosi, A.A. (2016). 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. Northeast-Midwest Institute and U.S. Geologic Survey, 2016.
[lxvii] Ibid.
[lxviii] Ibid.
[lxix] Ibid.
[lxx] Ibid.
[lxxi] Ibid.
[lxxii] Ibid.
[lxxiii] Ibid.
[lxxiv] Ibid.
[lxxv] Ibid.
[lxxvi] Ibid.
[lxxvii] Ibid.

[lxxviii] Ibid.
[lxxix] Ibid.
[lxxx] Ibid.
[lxxxi] USEPA (U.S. Environmental Protection Agency). 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Office of Research and Development, Washington, DC. EPA-600-R-16-236Fa. P. 8-74, 75.
[lxxxii] Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2012). An Exploratory Study of Air Quality near Natural Gas Operations. *Human and Ecological Risk Assessment: An International Journal*, Volume 20, Issue 1.
[lxxxiii] Ibid.
[lxxxiv] Ibid.
[lxxxv] Ibid.
[lxxxvi] Ibid.
[lxxxvii] Ibid.
[lxxxviii] Ibid.
[lxxxix] Ibid.
[xc] Ibid.
[xci] Ibid.
[xcii] Ibid.
[xciii] Southwest Pennsylvania Environmental Health Project at http://www.environmentalhealthproject.org/
[xciv] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 6.
[xcv] Marvin Resnikoff, Ph.D., Radioactive Waste Management Associates, "Comments on Marcellus Shale Development", October 2011.
[xcvi] http://www.epa.gov/radiation/radionuclides/radium.html#inbody
[xcvii] Marvin Resnikoff, "Memorandum, DRBC Draft Regulation Comments", Radioactive Waste Management Associates, February 19, 2018, p. 2.
[xcviii] Steven Habicht, Lars Hanson and Paul Faeth, "The Potential Environmental Impact from Fracking in the Delaware River Basin", August 2015, p. 53 - 61.
[xcix] Ibid.
[c] Ibid.
[ci] Ibid.
[cii] Ibid.
[ciii] Ibid. p. 63 - 72.
[civ] Ibid.
[cv] Ibid.
[cvi] Ibid.
[cvii] Ibid.
[cviii] Eric A. Kort, Christian Frankenberg, Keeley R. Costigan, Rodica Lindenmaier, Manvendra K. Dubey, Debra Wunch "Four corners: The largest US methane anomaly viewed from space", First published: 9 October 2014**.** http://onlinelibrary.wiley.com/enhanced/doi/10.1002/2014GL061503/
[cix] Intergovernmental Panel on Climate Change (IPCC). 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*
[cx] http://www.pnas.org/content/early/2017/01/03/1612066114.full
[cxi] PSE Healthy Energy, "Lifecycle Greenhouse Gas Emissions Associated with Projected Future Marcellus Development", 2017.
[cxii] https://www.epa.gov/climate-impacts/climate-impacts-water-resources
[cxiii] Steven Habicht, Lars Hanson and Paul Faeth, "The Potential Environmental Impact from Fracking in the Delaware River Basin", August 2015, p. 59 - 61.
[cxiv] Robert W. Howarth Ph.D., "CSSD Performance Standards: Impact on Greenhouse Gas Emissions", Unsafe and Unsustainable, Delaware Riverkeeper Network, 2014.
[cxv] Ibid. p. 19-23.
[cxvi] https://www.washingtonpost.com/news/energy-environment/wp/2016/12/11/atmospheric-levels-of-methane-a-powerful-greenhouse-gas-are-spiking-scientists-report/?utm_term=.445d31cff224
[cxvii] Robert Howarth: The David R. Atkinson Professor of Ecology and Environmental Biology, Cornell University, "COP21 Reflections on the Historic Paris Climate Agreement", Tompkins Public Library, New York (transcript), February 3, 2016.
[cxviii] Eric A. Kort, Christian Frankenberg, Keeley R. Costigan, Rodica Lindenmaier, Manvendra K. Dubey, Debra Wunch "Four corners: The largest US methane anomaly viewed from space", First published: 9 October 2014**.** http://onlinelibrary.wiley.com/enhanced/doi/10.1002/2014GL061503/

[cxix] Tom Gleeson, et.al, "Water balance of global aquifers revealed by groundwater footprint", published on line 6.1.12.
[cxx] Carmen Nobel, "Water, Electricity, and Transportation: Preparing for the Population Boom", *Working Knowledge,* 3.14.11.
[cxxi] Tom Gleeson, et.al, "Water balance of global aquifers revealed by groundwater footprint", published on line 6.1.12.
[cxxii] FracTracker Alliance, "Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin", March 20, 2018, p. 6.
[cxxiii] http://www.post-gazette.com/powersource/companies/2018/01/15/These-days-oil-and-gas-companies-are-super-sizing-their-well-pads/stories/201801140023
[cxxiv] http://investordiscussionboard.com/boards/ind-energy/these-days-oil-and-gas-companies-are-super-sizing-their-well-pads
[cxxv] U.S. EIA, https://www.eia.gov/todayinenergy/detail.php?id=35512, accessed 3.28.2018.
[cxxvi] Excel sheet document provided by PADEP: https://bit.ly/2J22o59
[cxxvii] Ibid. p. 7.
[cxxviii] Ibid. p. 13.
[cxxix] Ibid. p. 7.
[cxxx] Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018, p.5-6.
[cxxxi]Ibid. p.6.
[cxxxii] Ibid. p. 6-7.
[cxxxiii] Ibid. p. 7.
[cxxxiv] Ibid. p. 7.
[cxxxv] Ibid. p. 7-8.
[cxxxvi] Ibid. p.8.
[cxxxvii] Schmid & Company, Inc., "Comments on Proposed Regulations of the Delaware River Basin Commission Concerning High Volume Hydraulic Fracturing to Produce Oil and Gas, 3.18.2018, p. 9.
[cxxxviii] Instream Flows for Riverine Resource Stewardship, Instream Flow Council, Cheyenne, Wyoming, 2004, page178.
[cxxxix] Instream Flows for Riverine Resource Stewardship, Instream Flow Council, Cheyenne, Wyoming, 2004, p.178-179
[cxl] Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018, p. 14.
[cxli] "Review of XTO Energy Oquaga Creek Withdrawal, DRBC Docket D-2010-022-1", Peter Demicco, Demicco and Associates, 5.9.11.
[cxliicxlii] Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018, p. 8-9.
[cxliii] Hutson, S.S., Linsey, K.S., Ludlow, R.A., Reyes, Betzaida, and Shourds, J.L., 2016, Estimated use of water in the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania, 2010: U.S. Geological Survey Scientific Investigations Report 2015–5142, 76 p., http://dx.doi.org/10.3133/sir20155142. P. 30, et seq.
[cxliv] Ibid. p. 9.
[cxlv] Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018, p.9-10.
[cxlvi] Ibid. p. 11.
[cxlvii] Ibid. p. 2.
[cxlviii] Ibid. p. 12.
[cxlix] Ibid. p.13-14.
[clcl] US General Accountability Office, ***Information on the Quantity, Quality, and Management of Water Produced During Oil and Gas Production***, GAO-12-56, January 2012.
[cli] Ibid.
[clii] U.S. Dept. of Energy, Argonne National Laboratory, "A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane", January 2004.
[cliii] Marvin Resnikoff, Ph.D., Radioactive Waste Management Associates, "Comments on Marcellus Shale Development", October 2011.
[cliv] US General Accountability Office, ***Information on the Quantity, Quality, and Management of Water Produced During Oil and Gas Production***, GAO-12-56, January 2012.

[clv] New York State Department of Environmental Conservation, ***Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and other Low-Permeability Gas Reservoirs***, September 2011. http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf
[clvi] Ibid.
[clvii] NYSDEC Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program (DSGEIS), 2009, Tables 5-8 and 5-9, p. 5-109 .
[clviii] New York State Department of Environmental Conservation, ***Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and other Low-Permeability Gas Reservoirs***, September 2011, Table 5.9.
[clix] USEPA Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (2016), Tables C -11, C-13, C-15, C-17, C-19.
[clx] USEPA, Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States", EPA-600-R-16-236Fa, December 2016 www.epa.gov/hfstudy AND New York State Department of Environmental Conservation, Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and other Low-Permeability Gas Reservoirs, September 2011, Table 6.1.
[clxi] NRDC Document, "In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater", May 2012 d:12-05-A, Table 1.
[clxii] Yale University School of Public Health, https://publichealth.yale.edu/news/article.aspx?id=13714.
[clxiii] Ibid.
[clxiv] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at ES-45 to ES-46 and 9-1. EPA Report # 600/R-16/236F. See https://www.epa.gov/hfstudy.
[clxv] Dusty Horwitt, Environmental Issues Concerning Hydraulic Fracturing, Volume 1 (Kevin A. Schug and Zachariah L. Hildenbrand, eds.), at 101 (2017).
[clxvi] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 9-1, 10-25. EPA Report # 600/R-16/236F. See https://www.epa.gov/hfstudy.
[clxvii] FracFocus. See http://fracfocus.org/.
[clxviii] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 9-1, 10-25. EPA Report # 600/R-16/236F. See https://www.epa.gov/hfstudy.
[clxix] 2010 NWRI Final Project Report on "Source, Fate, and Transport of Endocrine Disruptors, Pharmaceuticals, and Personal Care Products in Drinking Water Sources in California", May 19, 2010. http://www.nwri-usa.org/pdfs/cecresearchprofile.pdf
[clxx] Vandenberg et. al., "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Nonmonotonic Dose Responses", The Endocrine Society, doi:10.1210/er.2011-1050, 3.14.12.
[clxxi] Laura Vandenberg, Tufts University, "There Are No Safe Doses for Endocrine Disruptors", Environmental Health News, 3.12.
[clxxii] Linda S. Birnbaum, Director, NIEHS and NTP, National Institutes of Health, U.S. Department of Health and Human Services, "Environmental Chemicals: Evaluating Low-Dose Effects", doi:10.2189/ehp.1205179, Environmental Health Perspectives, Vol. 120, Number 4, April 2012.
[clxxiii] Partnership for Policy Integrity, ***Toxic Secrets: Companies Exploit Weak US Chemical Rules to Hide Fracking Risks**,* April 7, 2016. http://www.pfpi.net/toxic-secrets-companies-exploit-weak-us-chemical-rules-to-hide-fracking-risks
[clxxiv] Ibid.
[clxxv] Ibid.
[clxxvi] Ibid.
[clxxvii] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 5.
[clxxviii] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 2.
[clxxix] Ibid. p. 3.
[clxxx] PADEP "Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges", April 11, 2009.
[clxxxi] http://www.duq.edu/academics/schools/natural-and-environmental-sciences/academic-programs/environmental-science-and-management/3-rivers-quest;

[clxxxii] http://www.post-gazette.com/local/south/2011/11/04/Bromide-levels-in-Monongahela-River-rose-in-2010-remain-high/stories/201111040150.
[clxxxiii] http://www.record-courier.com/news/20121113/bromide-pollution-persists-in-allegheny-river-in-western-pa
[clxxxiv] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 3-4.
[clxxxvclxxxv] Ibid. p. 4.
[clxxxvi] Swanson, VE, "Oil Yield and Uranium Content of Black Shales," USGS paper 356-A, 1960.
[clxxxvii] Resnikoff, Marvin, ""Review of Pennsylvania Department of Environmental Protection Technologically Enhanced Naturally Occurring Radioactivity Materials (TENORM) Study Report", Dec. 2015.
[clxxxviii] Ibid.
[clxxxix] New York State Department of Environmental Conservation, Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and other Low-Permeability Gas Reservoirs, September 2011, Table 5.24.
[cxc] Nathaniel R. Warner*, Cidney A. Christie, Robert B. Jackson, and Avner Vengosh, "Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania", Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina 27708, United States, Environ. Sci. Technol., 2013, 47 (20), pp 11849–11857, DOI: 10.1021/es402165b http://pubs.acs.org/doi/abs/10.1021/es402165b
[cxci] Marvin Resnikoff, Ph.D., Radioactive Waste Management Associates, "Comments on Marcellus Shale Development", October 2011.
[cxcii] Marvin Resnikoff, Ph.D., "Review of Pennsylvania Department of Environmental Protection Technologically Enhanced Naturally Occurring Radioactivity Materials (TENORM) Study Report", Dec. 2015.
[cxciii] Marvin Resnikoff, "Memorandum, DRBC Draft Regulation Comments", Radioactive Waste Management Associates, February 19, 2018, p. 2.
[cxciv] Ibid. p. 3.
[cxcv] Ibid. p. 4.
[cxcvi] Marvin Resnikoff, Ph.D., "Review of Pennsylvania Department of Environmental Protection Technologically Enhanced Naturally Occurring Radioactivity Materials (TENORM) Study Report", Dec. 2015.
[cxcvii] Marvin Resnikoff, "Memorandum, DRBC Draft Regulation Comments", Radioactive Waste Management Associates, February 19, 2018, p.1.
[cxcviii] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 3-4.
[cxcix] Kaiser Engineers, California, Final Report to the State of California, San Francisco Bay-Delta Water Quality Control Program, State of California, Sacramento, CA (1969).
[cc] C.M. Hogan, Marc Papineau et al. Development of a dynamic water quality simulation model for the Truckee River, Earth Metrics Inc., Environmental Protection Agency Technology Series, Washington D.C. (1987).
[cci] DRBC Water Quality Regulations, 18 CFR, Part 410 http://www.state.nj.us/drbc/library/documents/WQregs.pdf
[ccii] http://www.state.nj.us/drbc/library/documents/dockets/interactive-map/1970-072-5.pdf
[cciii] http://www.state.nj.us/drbc/library/documents/dockets/interactive-map/1996-021-4.pdf
[cciv] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 6-7.
[ccv] PETER M. CHAPMAN, "WHOLE EFFLUENT TOXICITY TESTING—USEFULNESS, LEVEL OF PROTECTION, AND RISK ASSESSMENT", Environmental Toxicology and Chemistry, Vol. 19, No. 1, pp. 3–13, 2000, q 2000, SETAC, 0730-7268/00.
[ccvi] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 5.
[ccvii] Glenn C. Miller, Ph.D., "Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations", March 20, 2018, p. 2.
[ccviii] Piotr Parasiewicz, PhD, A.Prof., "Ecological review of the DRBC Draft 18 CFR Parts 401 and 440 Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities," February 2018, p. 12-13.
[ccix] FracTracker Alliance, "Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin", March 20, 2018, p. 9-11.
[ccx] Ibid. p. 13.
[ccxi] Ibid. p. 13.
[ccxii] Ibid. p. 13.
[ccxiii] Ibid. p. 11

Tom Myers, Ph.D.
Hydrologic Consultant
6320 Walnut Creek Road
Reno, NV 89523
775-530-1483
tommyers1872@gmail.com

Technical Memorandum

Review of Proposed Natural Gas Regulations as Proposed by the Delaware River Basin Commission

March 12, 2018

INTRODUCTION

The Delaware River Basin Commission (DRBC) published Draft Natural Gas Regulations on 30 November 2017 as proposed amendments to its Administrative Manual and Special Regulations regarding natural gas development activities, as well as additional clarifying amendments (18CFR401.35, 18CFR401.43, and 18CFR440). The proposed regulations include: (a) a prohibition on the production of natural gas utilizing horizontal drilling and hydraulic fracturing within the Basin 18CFR440.3(b), (b) provisions for allowing the 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 elsewhere (18CFR440.5), and (c) regulation of the inter-basin transfer of water and wastewater for purposes of natural gas development where permitted elsewhere (18CFR440.4).

There are two primary pathways for contaminants to reach waters of the Delaware River Basin –across the ground surface and through groundwater. The primary source of contaminants on the ground surface is spills from operations or transportation. The proposed DRBC regulations would not allow fracking within the watershed but would allow the importation of fracking waste fluids, which could be spilled where they can either run off into surface water or percolate into the ground and contaminate shallow groundwater.

This technical memorandum provides and discusses several reasons why the DRBC should not allow the importation of any wastewater, or produced water, into the Delaware River Basin (DRB) for treatment or disposal. These include the fact that spills of waste water are a hazardous waste spill that can contaminate soil and provide a source of contamination to shallow groundwater and streams for a long period. Disposal of waste by spreading onto roads is really no different than a spill, with contaminants spread along the roadway. The most hazardous aspects of road-spreading is the chemicals in the brine, which are similar whether the source is unconventional shale or conventional gas. Brine from any oil and gas wells should not be spread onto roads to prevent contamination.

There are many reasons to ban fracking within the DRB based on the actual process. In addition to spills, there are many pathways for contamination to reach shallow groundwater from either the well bore or the targeted shale. The pathways include fracture and faults, faulty wellbores, and seismic activity mobilizing gas at shallow levels. The memorandum discusses these in detail and refutes the many arguments presented by industry to counter them.

GROUNDWATER POLLUTION DUE TO SPILLS OF WASTEWATER IMPORTED INTO THE BASIN

The proposed regulations would allow the importation of "produced water" or CWT wastewater, with submission to the Commission for determination as to whether the project would impair or conflict with the Comprehensive Plan (18CFR401.35.b(18)). Specifically, the rule allows "[t]he importation, treatment, or discharge to basin land or water of "produced water" or CWT wastewater as those terms are defined in 18 CFR 440.2" (Id.). CWT wastewater presumably is wastewater reporting to a centralized waste treatment (CWT) facility as defined in 18 CFR440.2, which includes any hazardous or non-hazardous industrial waste or wastewater, presumably not limited to fracking waste. Produced water is 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 formation" (18 CFR 440.2). The regulations therefore would allow importation of water that comes from the well at any point during the hydraulic fracturing process or the period afterwards.

The regulation would allow the discharge of the wastewater to waters, and presumably that would include discharge to groundwater. Presumably, that would include disposal through injection wells, although there are only eight current injection wells within Pennsylvania permitted for oil and gas (O&G) waste disposal. Those wells are in western Pennsylvania, outside of the DRB. Injection would be regulated by the US Environmental Protection Agency (EPA), if proposed. In general, Pennsylvania is considered unsuitable geologically for the disposal of O&G wastewater through injection wells.

A groundwater flow pathway unique to headwaters regions within the DRB is shallow transport from spills or leaks of surface storage. The distance from any point on a drainage basin to a first-order stream is short, on the order of a few hundred to perhaps a thousand feet. Shallow aquifers especially on ridges are thin (Taylor 1984) and the water table follows the topography. Thus, spills would move as interflow from the source to streams relatively quickly, on the order of days. As outlined in the next section, this vulnerability is a reason for the DRBC to prohibit the import of wastewater to the DRB for any reason. The same reasoning also applies to the potential for road spreading of brine to contaminate DRB waters. DRBC should not allow the import of any wastewater to prevent any pollution from that wastewater within the DRB.

Pollution from Spills

Contamination can reach surface water near a gas well by flowing across the ground surface through small drainages to streams downhill from the source. The potential for spills or leaks to follow such a path is clear, but there is little specific research. Lefebvre (2017) found that spills or other surface releases represent the most probable mechanism leading to groundwater contamination. Most research concerning spills of fluids associated with O&G development focuses on well pad spills. For example, EPA's review of fracking-related spills was limited to spills near the pad (EPA 2015). In a substantial review paper concerning the impact of shale gas on regional water quality (Vidic et al. 2013), the authors cited just one report from grey literature (Considine et al. 2012) regarding spills and one journal article from the early 1980s regarding spills transporting through shallow groundwater (Harrison 1983). A more recent article (Maloney et al 2017) summarized details of the threats of spills at the well site harming nearby streams.

Considering O&G development in four states, Pennsylvania, Colorado, New Mexico, and North Dakota, Maloney et al (2017) reviewed data from 6622 spills that occurred for 21,300 unconventional wells, a ratio of one spill for every 3.2 wells. The proximity to streams was smallest in Pennsylvania, with an average distance of 268 meters (Id.). This could be due to the higher density of streams in a humid-regions state like Pennsylvania as compared to the other states. Over the four states, 7% of spills were within 100 feet of a stream, and 5.3% of the spills in Pennsylvania were within this distance. Maloney et al (2017) reported that the required setback in Pennsylvania is 100 feet, so decisionmakers should not rely on compliance with regulations to protect streams. The statistics regarding spills shows that DRBC is correct to ban fracking within the DRB to protect streams within the basin.

The frequency and volume of spills during transport should not differ from spills during the transport of hazardous waste overall because of similar methods. Public Source (2014) analyzed records of 40,000 spills occurring in Pennsylvania between 1971 and 2013, which included spills on highways, waterways, and airway (www.publicsource.org/pa-fifth-in-the-nation-in-hazardous-spills/). More than 12,500 events have occurred since 2000. Fifty-nine of the events caused evacuations and 96 events closed transportation arteries. Spills were rated as serious 2% of the time. It is fair to conclude that serious spills of fracking waste would occur within the DRB if the DRBC allows importation and that some of those spills will be serious.

Transportation-related pathways were the fourth largest of 14 potential pathways for spills to reach water supplies, where the third largest was the unknown pathway (or pathway unreported) (Patterson et al 2017). For Pennsylvania, the average was 1.7 transportation-related spills for every thousand well years. Of the total number of spills in Pennsylvania, human error was the number one cause for spills with an identified cause. The high number of unidentified causes and pathways in Pennsylvania was likely due to the State not requiring this information be reported as it is in Colorado and New Mexico.

Spills of fracking fluids include hydrocarbons and petroleum distillates which linger in the soils and are difficult to clean up (Maloney et al 2017), regardless of whether the spill is at the pad or during transportation. Ripendra (2016) found contamination by wastewater disposal and accidental leaks and spills of wastewater and chemicals used during drilling and the hydraulic fracturing process to be two of the four primary threats to water quality posed by fracking, with the other two being well integrity related.

Drollette et al (2015) found in the Marcellus region an elevated concentration of diesel range organic chemicals linked to hydraulic fracturing fluid within shallow groundwater. They associated it with spills, primarily at the well sites, by correlating DRO concentration with distance from wells. They did not test for distance from other types of spills, presumably because the location of those spills is not available in the data base. In addition to showing potential for long-term contamination near well sites, these results suggest there would be long term DRO contamination near all spill sites. The contamination from spills into clay-rich soils is likely to linger as much as 25 times longer than for gravely soils (Cai and Li 2017). The contamination is also likely to contain higher concentrations of various radioactive substance (Lauer and Vengosh 2016).

Road Spreading of Brine

It is common in the United States to dispose of O&G produced brine by spreading it on roads for dust or ice control. No jurisdictions in Canada allow the spreading of O&G wastewater on roads (Goss et al 2015). The popular press describes the use and unpopularity of the process in northern and western Pennsylvania (for example, http://www.newsweek.com/oil-and-gas-wastewater-used-de-ice-roads-new-york-and-pennsylvania-little-310684). However, Pennsylvania does not currently allow the use of brine from unconventional shale deposits for road spreading (PDEP 2017), it does allow brine from conventional deposits. Dr. Avner Vengosh was quoted in the Newsweek article cited above as stating there is not much difference because it is the brine chemicals, salt, ammonium, naturally occurring source of radioactive materials (NORM), and others, that make the brine deleterious to shallow groundwater, not the organic fracking fluid chemicals. Brown (2014) also noted the high levels of NORM, which can be technologically concentrated in brine.

Skalak et al (2014) examined sediments around a series of sites that had received road-spread brine. They found that concentrations in the sediments had increases of radium, strontium, calcium, and sodium of 1.2, 3.0, 5.3 and 6.2 times, respectively, as compared to background concentrations that did not have road spreading of brine. The authors also found a variability of up to 30 times, meaning that some areas could received concentrated runoff. The concentrations could be limited due to surface runoff dissolving the cations or infiltration flushing it to shallow groundwater. These results indicate that road spreading of O&G brine can contaminate soils and that those soils can be a source of contamination to shallow groundwater and surface water. It does not appear that brine is used on roads at this time within the DRB, and there is no reason the DRBC should allow it in the future.

GROUNDWATER POLLUTION DUE TO THE FRACKING PROCESS

The proposed DRBC regulations would prohibit fracking, at least that using greater than 300,000 gallons of fracking fluid, (18CFR440.3(b)) because the Commission "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 …" (18CFR440.3(a)). The definition of high-volume hydraulic fracturing is hydraulic fracturing that uses 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" (18CFR440.2). The regulation would allow very small fracking operations (<300,000 gallons). Fracking of unconventional oil/gas formations generally requires substantially more fluid to adequately fracture the formation, although there is no formal minimum required amount. Hydraulic fracturing has other applications which generally use less fluids without chemicals; those that are relevant to the DRB are water well production, block cave mining, and rock stress testing (Adams and Row 2013).

There are multiple reasons that the prohibition of fracking is desirable, and the following sections discusses how the process of fracking, even if completed as designed, can contaminate shallow groundwater and surface water in the DRB.

Underground Paths

The most complex transport pathways for contaminants from fracking to reach Watershed lands occur underground, between the point of fracking and shallow groundwater or surface water. At least three different substances released by fracking can reach shallow groundwater or surface in the DRB – natural gas (shallow biogenic and deep thermogenic gas), formation brine, and fracking fluid. All would be part of produced water as defined by the proposed regulations if they transported up the well bore to shallow groundwater or surface water. These contaminants can follow pathways through natural faults and fractures, through abandoned wells or poorly constructed gas well, or a combination of both. This section discusses gas and liquid transport separately because the pathways and timescales are different.

Natural Gas Pathways

Many studies have highlighted the increase in CH_4 concentration[1] within one kilometer of fracked wells, with the CH_4 being identified as thermogenic (Darrah et al. 2014; Jackson et al. 2013; Osborn et al. 2011). Others have noted the presence of increased CH_4 in valley locations along faults and lineaments (Molofsky et al. 2013; Fountain and Jacobi 2000). Fractures caused by faulting provide pathways to the surface. Darrah et al. (2014) listed the following scenarios that can lead to higher methane concentrations in shallow groundwater:

(i) in situ microbial methane production;

(ii) natural in situ presence or tectonically driven migration over geological time of gas-rich brine from an underlying source formation or gas-bearing formation of intermediate depth (e.g., Lock Haven/Catskill Fm. Or Strawn Fm.);

(iii) exsolution of hydrocarbon gas already present in shallow aquifers following scenario 1 or 2, driven by vibrations or water level fluctuations from drilling activities;

(iv) leakage from the target or intermediate-depth formations through a poorly cemented well annulus;

(v) leakage from the target formation through faulty well casings (e.g., poorly joined or corroded casings);

(vi) migration of hydrocarbon gas from the target or overlying formations along natural deformation features (e.g., faults, joints, or fractures) or those initiated by drilling (e.g., faults or fractures created, reopened, or intersected by drilling or hydraulic fracturing activities);

[1] Natural gas is a mixture of carbon-chain gases, with CH4 (methane) being the most dominant.

(vii) migration of target or intermediate-depth gases through abandoned or legacy wells

Scenarios one and two are not anthropogenic, but fracking could enhance the second scenario (Gassiat et al. 2013; Myers 2012). Warner et al. (2012) and Llewellyn (2014) provide evidence for the type of brine movement discussed in scenario 2. Drilling or vibrations caused by fracking can release dissolved gas or change its transport through shallow groundwater so that it affects water wells. Because the vibrations caused by fracking are tantamount to a seismic vibration, earthquakes associated with increased fracking would likely also cause additional gas to be released.

The third scenario is a mechanism by which fracking releases gas into shallow groundwater through which it can flow to surface lands. Fracking-caused earthquakes could enhance the release of gas. The fourth and fifth scenario describes the potential movement of gas from depth along the well, due to faulty construction, to shallow groundwater. The sixth scenario is the movement of gas from the target formation through natural pathways, such as faults or fractures, to shallow groundwater. Where there are abandoned wells, scenario 7 is an obvious potential scenario, although it includes transport through bedrock to the abandoned well. Regardless of the mechanism causing methane to reach shallow groundwater, either as dissolved or buoyant gas, it would contaminate groundwater within the DRB. Groundwater discharges to streams and springs within the DRB.

Darrah et al. (2014) studied seven locations in Pennsylvania and one in Texas and found based on the amount of noble gases in the sample that scenario 6 is unlikely because the gases in the shallow groundwater did not resemble those that have followed a natural pathway from the shale to the shallow groundwater. The paper rules out transport of gas freshly liberated from the target shale through natural fractures because the diagnostic gas isotope ratios do not reflect the changes through fractionation that would occur as the gas migrates through the water-saturated crust. Their conclusion ignores the fact that the gas would be transported through the same formations whether from depth, the layer of the shale, or for up to a kilometer through shallow aquifers which are similar bedrock types. Darrah et al's conclusions also require that the gas undergo the same transformation in weeks as gas would have undergone in millions of years of brine transport to shallow groundwater. Leaks from deep formations that occurred at a storage facility in Tioga County reached shallow groundwater (Breen et al. 2007), which suggests the transport of gas through pathways not accepted by Darrah et al.

Other studies have documented the rate at which gas released by fracking can move through the groundwater. Gas tracers released during fracking were found at production wells 750 feet away from the source within days (Hammock et al 2014). They also found evidence of gas migration to a sandstone formation 3000 feet above the Marcellus shale (Id., Figure 33). A model study based on conditions found at the southwest Pennsylvania site used in Hammock et al. estimated that gas can flow from a well bore leak through a sandstone rock matrix to a well 170 m away in times ranging from 89 days to 17 years depending on conditions (Zhang et al 2014). Darrah et al. (2014) found several gas wells within one kilometer of fracked wells that experienced large increases in gas concentration between annual sampling events which suggests that gas transport of up to a kilometer occurred in a time period of less than a year.

Additional evidence of gas movement along faults through the earth's crust to shallow groundwater may be seen through studies concerning CO_2 sequestration. Shipton et al. (2004) found that fluids (liquid and gas) can move vertically through low permeability faults, including those otherwise considered to be sealed with calcite. Critically, gas migration is extremely heterogeneous with large fluxes occurring through high-permeability pathways resulting in large gas loads hitting very small areas (Annunnziatellis et al. 2008). The distribution of methane seeping through a fault is much more variable than the distribution of either helium or carbon dioxide following the same general pathway (Annunziatellis et al. 2008). These authors described the extreme variability in gas flow as the"'spot' nature of gas migration along spatially restricted channels" (Annunziatelis et al. 2008, p 363). Even along a single fault, the flux is highly variable and intersecting joints or faults add variability in an additional direction. The spot nature of gas flow is probably responsible for highly variable readings in domestic water wells even in small areas and for the fact that the concentration in some wells may decrease while in others it remains steady or increases.

There is evidence that water wells near fault zones will likely have more gas occurrences naturally, but it is also clear that fracking should increase the occurrence of gas in these areas. Drainages in Pennsylvania have more natural gas occurrences than other areas (Molofsky et al. 2013; Fountain and Jacobi 2000). Fountain and Jacobi (2000) mapped the presence of thermogenic NG in soils as a means of detecting underlying lineaments and fracture zones, based on the assumption of a fault/fracture connection between thermogenic gas sources and the surface. It is likely that anthropogenic gas, regardless of the source (the well bore or the source shale formation), can follow faults and fractures to shallow groundwater. If fracking releases gas from shale and/or increases the connection between the shale and fracture zones, it seems likely that fracking will be responsible for increasing gas in the streams underlain by fracture systems (Jackson et al. 2013; Osborn et al. 2011) in the Basin.

Drainages in northeast Pennsylvania likely coincide with fault/fracture zones, as described by Taylor (1984):

> Wells in higher topographic positions (hilltops and hillsides) have smaller yields than those in lower topographic positions (valley, gullies, and draws). Valleys and draws often form where the rocks are most susceptible to physical or chemical weathering. Hilltops are generally underlain by more resistant rocks. Lithologic variations and weaknesses in rocks caused by bedding partings, joints, cleavage, and faults promote rapid weathering and can produce low areas in the topography. These types of geologic features often occur in high-permeability zones which yield significant amounts of water to wells. (Taylor 1984, p 29).

Although Taylor (1984) studied streams in the Susquehanna River basin, his observations apply to headwaters streams in the DRB. His description is of a pathway for gas to follow from O&G wells to streams.

The previous paragraphs describe the various pathways gas can flow from a fracked well to shallow groundwater, streams, and springs on nearby land. Whether the source is gas released directly from the shale or the well bore and whether the pathway is along a faulty well bore or natural fractures, these findings point to a significant risk that NG wells with fracking within the DRB significantly increase the risk for gas reaching shallow groundwater near stream channels. The chance is probably highest for higher order streams in fault-controlled valleys in the DRB, such as the Lackawanna River or DRB headwaters' drainages in the Catskill Mountains.

Most studies and monitoring of gas development impacts on surface water, either streams or springs, focus on contaminants easily carried through the water, such as geochemical indicators such as chloride or suspended sediment (Olmstead et al. 2014) or fracking fluids. It is common to ignore the presence of methane in streams. Methane degases from surface water, but without sufficient aeration, the methane decreases the dissolved oxygen in the surface water which would have severe aquatic effects. Essentially, methane discharges to streams increase the dissolved methane content of the stream thereby decreasing the dissolved oxygen content for areas near the methane source. This can lead to dead zones just as anything else that depletes oxygen.

Liquid Pathways

Formation brine naturally flows through faults and fractures from the Marcellus (Warner et al. 2012) or other deep Appalachian basins to shallow groundwater (Llewellyn 2014) based on geochemical and isotopic evidence. Both papers warn that these connections could allow more rapid brine flow or portend the flow of fracking fluid to shallow groundwater due to increased pressure or enhanced connections due to fracking. At least three published studies have documented fracking fluid reaching drinking water wells (Llewelyn et al 2015, DiGiulio et al. 2011; EPA 1987) and litigation settlements have prevented disclosure of the facts in similar circumstances. Llewelyn et al (2015) documented transport between a fault plane/well intersection 1600 feet BGS and a shallow aquifer.

Model studies for years have simulated the potential for deep brine to circulate to the surface naturally (Deming and Nunn 1991; Person and Baumgartner 1995) or in conjunction with deep waste or CO2 injection (Birkholzer and Zhou 2009)). The role of fractures to allow flow through shale layers has also been known for years, with Bredehoeft et al. (1983) finding that at a field scale, the vertical conductivity of shale is up to three orders of magnitude greater than the conductivity estimated from a column in a laboratory.

Recent model studies have estimated that fluids could flow from the Marcellus, or similar shale layers in similar sedimentary basins, to shallow aquifers naturally and that the flow could be enhanced by fracking to occur in less than 10,000 years depending on assumed conditions (Taherdangkoo et al 2017, Wilson et al 2017, Chesnauw et al. 2013; Gassiat et al. 2013; Kissinger et al. 2013; Myers 2012). Most modelers found conditions that would allow transport of liquids to occur due to fracking within a couple hundred years for some of the conditions they simulated. All of the model studies found the most rapid transport could occur through a vertical fault system. The primary difference in the time for transport depended on the conceptualization of formations and the hydrogeologic parameterization.

Myers (2012) found that transport from the Marcellus to shallow aquifers could occur over a period from 10 to more than a thousand years, depending on the conductivity assumed to result from fracking -- his model had the horizontal gas well intersecting a vertical fault connecting the shale to the near-surface. Gassiat et al. (2013) modeled a high permeability, continuous, 10-m wide fault zone from the shale to the shallow groundwater with fracking simulated as a change in permeability over a 2-km long, 150-m thick zone. Kissinger et al. (2013) simulated a continuous 30-m thick vertical fault with a head drop of up to 60 m to drive a plume of fracking fluid into the lower aquifer. After 30 years under this scenario, simulated fracking fluid had reached the shallow aquifer. Lateral migration of contaminants occurred at rates up to 25 m/y (Lange et al. 2013). Chesnauw et al. (2013) modeled flow along a fracture pathway between a target shale zone and surface aquifer in a two-dimensional framework, 3000-m long by 3000-m deep and 1 m thick. The modeling studies utilized generic stratigraphic and topographic cross-sections with idealized formation properties due to a lack of specific aquifer data. Also, they considered flow through a fault, but likely underestimated the potential for preferential flow through small but highly permeable fractures even within a preferential flow zone. Taherdangkoo et al (2017) found that upward fluid migration to a shallow aquifer depended on the characteristics of the fault, but argued the probability remained small; they did not consider out-of-formation fractures intersecting the fault or a natural upward gradient in the fault zone due to common basin topographic circulation

(Deming and Nunn 1991). Wilson et al (2017) used model simulations to show that fracking fluid could reach shallow aquifers through fault zones from a target shale greater than 2000 meters bgs. Travel time was quicker for increased induced fracture extent (out of formation fractures), absence of deep high hydraulic conductivity strata, and low fault hydraulic conductivity. The authors found that high conductivity horizontal formations intersecting the fault and high conductivity faults allowed fluids to leak off thereby reducing the mass reaching shallow groundwater.

At least two studies (Engelder et al. 2014; Flewelling and Sharma 2013) have attempted to counter the model study by arguing that brine and fracking fluid cannot reach shallow aquifers due to stratigraphic barriers, lack of a driving force, the Marcellus being dry, and imbibition removing fracking fluid like a sponge, etc. Both studies have serious flaws including their "facts" being countered by many other studies.

Flewelling and Sharma considered the permeability of the bulk formations and ignored potential fault connections between the shale and the surface. They incorrectly claimed that other studies (Myers 2012) rely on out-of-formation fracturing to provide a pathway all the way to shallow groundwater. The modeling studies cited above assume a fault connection to the top of the shale so that fracking fluid only must reach the top of the shale. Out-of-formation fractures that extend above the shale (Hammock et al. 2014; Fisher and Warpinski 2011) may short circuit the pathway making transport faster than simulated in the studies cited herein. Out-of-formation fractures are not required for fracking fluid to reach shallow groundwater. Flewelling and Sharma mistakenly assume the transport would have to be widespread across a large area when the reality is that brine migration, and transport of fracking fluid, would focus flow to spatially restricted discharge zones, such as faults, that lead to springs or the shallow groundwater beneath valleys (Deming and Nunn 1991).

Engelder et al. (2014) also makes arguments not supported by facts. The first is that potential transport as simulated by Myers (2012) and others depends on "single phase Darcy Law physics" which they claim is inappropriate when there is gas and water present. They are wrong because most of the gas occurs within the bulk matrix of the shale layers and most flow occurs in fractures and joints which are predominantly water. This may be seen even in the well log presented by Engelder et al. showing significant free water in a one-meter portion of the shale where the core likely crosses a significant fracture zone. The formations above and below the shale in the well log are also almost saturated. Additionally, the large model scale employed by the models renders multiphase flow considerations irrelevant, as argued for modeling CO2 sequestration as a single phase (Cihan et al. 2011).

The second is they claim that even if all the salt in the Marcellus shale reached the shallow groundwater it would be so diluted as to be irrelevant. The fallacy in their argument is they assume the salt disperses evenly and instantaneously through shallow groundwater when reality is a high concentration flow would enter at a small fault zone intersecting the shallow aquifers, such as at Salt Springs State Park.

Their third argument is they believe that all fracking fluid not returning to the surface as flowback becomes imbibed in the shale. Birdsell et al (2015) also argues that Myers (2012) and other modeling studies have ignored imbibition. Imbibition is a process whereby liquid enters the micropores and becomes bound to the shale matrix, like water soaking into a sponge. Certainly, some fracking fluid becomes imbibed, so their argument applies to fracking fluid that remains in the shale. Birdsell et al (2015) rely on theoretical calculations dependent on theoretical, not measured, parameters. They estimate a range from 15 to 95% of the injected fluid being imbibed. Obviously, much injected fluid is not imbibed even at their estimate at the 15% end of the range.

Much fracking fluid leaves the shale through out-of-formation fractures which extend as much as 1500 feet above the Marcellus shale (Hammock et al. 2014; Fisher and Warpinski 2011). Hammock et al. (2014) documented 10,286 microseismic events as much as 1900 feet above the shale from 56 fracking stages for six Marcellus wells, including many events that extended above the Tully limestone, which had been considered a barrier to fracturing. The fractures provide a pathway from the shale to much more permeable formations, including those that consist of sandstone or limestone, near shallow groundwater. The new fractures also potentially connect with natural fractures. The modeling studies (Taherdangkoo et al 2017, Gassiat et al 2013, Myers 2012) apply to injected fluids that leave the shale and are by design not imbibed. It simply cannot be argued, therefore, that all fracking fluid that does not flowback to the surface through the well remains within the shale.

The Marcellus shale is also not essentially dry unless one considers only the bulk matrix in which most of the methane is bound. As shown on the well log presented by Engelder et al., fracture zones with higher secondary permeability within the shale contain free water. It is these zones that fracking fluid flows through. New fractures would connect zones of secondary permeability that contain free water, or brine. Fracking provides a pathway for Marcellus brine, the free water, to flow to the gas well, probably becoming dominant after the fracking fluid remaining most closely near the well goes back up the well as flowback.

Haluszczak et al (2012) showed that brine dominated the flowback, based on the rapid increase in concentrations of various constituents, including TDS, Cl, Br, Na, Ca, Sr, Ba, and Ra, in the flowback to levels several times that of seawater. Flowback was not fracking fluid that had dissolved rock minerals from the shale as claimed by Engelder et al. Kohl et al. (2014) used strontium isotope ratios found in flowback to isolate the source formation; the strontium signatures would not be as representative of the source formation if its presence was due only to high velocity dissolution during fracking. Rowan et al. (in press, abstract, emphasis added) conclude that the "δ18O values and relationships between Na, Cl, and Br, provide evidence that the water produced after compositional stabilization is **natural formation water**, whose salinity originated primarily from evaporatively concentrated paleoseawater".

In other words, the shale is not dry but contains a substantial amount of naturally occurring brine that fracking causes to be released from the shale. It is clear therefore that scenario 2 (Darrah et al. 2014) facilitating the movement of brine from depth to shallow groundwater could also portend the movement of fracking fluid or enhanced flow of brine due to fracking. The flow could occur much faster than occurs naturally for brine because of the increased permeability due to fracking, fracking fluid pushing brine from the shale, and the added pressure due to fracking injection. This contaminant movement threatens water sources in the DRB if the DRBC allows fracking within the DRB.

Contamination of Groundwater Due to Fracking

The proposed regulations properly prohibit fracking within the Delaware watershed. This section has described how fracking has been shown to cause pollution or how it is likely to do so in the future, both through the actual process of fracking and from well bore leaks. The potential for contaminants to reach groundwater through these pathways is a good reason for banning the process within the watershed. DRBC is correct in doing so.

REFERENCES

Adams J, Row C (2013) Differentiating applications of hydraulic fracturing. Chapter 18 in Bunger AP, McLennan J, Jeffrey R (eds), Effective and Sustainable Hydraulic Fracturing.

Annunziatellis A, Beaubien SE, Bigi S, Ciotoli G, Coltella M, Lombardi S(2008) Gas migration along fault systems and through the vadose zone in Latera caldera (central Italy): Implications for CO2 geological storage. Int J Greenh Gas Contr 2:353-372. Doi:10.1016/j.ijggc.2008.02.003

Birdsell DT, Rajaram H, Lackey G (2015) Imbibition of hydraulic fracturing fluids into partially saturate shale. Water Resour Res 51:6787-6796, doi 10.1002/2015WR017621

Birkholzer JT, Q Zhou (2009) Basin-scale hydrologic impacts of CO2 storage: Regulatory and capacity implications. Int J Grnhs Gas Control

Bredehoeft JD, CE Neuzil, PCD Milly (1983) Regional Flow in the Dakota Aquifer: A Study of the Role of Confining Layers, U.S. Geological Survey Water-Supply Paper 2237.

Breen KJ, K Revesz, FH Baldassare, SD McAuley (2007) Natural gases in ground water near Tioga Junction, Tioga County, North-Central Pennsylvania – Occurrence and of isotopes to determine origin, 2005. US Geological Survey Scientific Investigations Report 2007-5085. 65 p.

Brown VJ (2014) Focus: Radionuclide in Fracking Wastewater. Env Health Persp 122(2):A50-A55.

Cai Z, Li L (2016) How long to natural waters "remember" release incidents of Marcellus Shale waters: a first order approximation using reactive transport modeling. Geochem Tran 17:6. Doi 10.1186/s12932-016-0038-4.

Cai Z, Ofterdinger U (2014) Numerical assessment of potential impacts of hydraulically fractured Bowland Shale on overlying aquifers. Wat Resour Res doi:10.1002/2013WR014943

Chesnaux R, dal Soglio L, Wendling G (2013) Modelling the impacts of shale gas extraction on groundwater and surface water resources. Presented at GEOMontreal 2013, September 29 – October 3, 2013, Montreal, Quebec

Cihan A, Birkholzer JT, Zhou Q (2013) Pressure buildup and brine migration during CO2 storage in multilayered aquifers. Groundwater 51(2):252-267, doi: 10.1111/j.1745-6584.2012.00972.x.

Considine TJ, Watson RW, Considine NB, Martin JP (2013) Environmental regulation and compliance of Marcellus shale gas drilling. Environ Geosci 20:1-16

Darrah, T.H, A Vengosh, R.B. Jackson, N.R. Warner, and R.J.Poreda. 2014. Nobel gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales. PNAS Early Edition. Doi:10;.1073/pnas.1322107111.

Deming D, Nunn JA (1991) Numerical simulations of brine migration by topographically driven recharge. Journal of Geophysical Research 96(B2):2485-2499.

DiGiulio, D. C., R. T. Wilkin, C. Miller, and G. Oberly (2011), DRAFT: Investigation of Ground Water Contamination near Pavillion, Wyoming, U.S. Environmental Prodection Agency, Office of Research and Development.

Drollette BD, Hoelzer K, Warner NR, Darrah TH, Karatum O, O'Connor MP, Nelson RK, Fernandez LA, Reddy CM, Vengosh A, Jackson RB, Elsner M, Plata DL (2015) Elevated levels of diesel range organic compounds in groundwater near Marcellus gas operations are derived from surface activities. Proc Natl Acad Sci 112(43):13184-13189. Doi 10.1073pnas.1511474112.

Engelder T, Cathles LM, Bryndzia LT (2014) The fate of residual treatment water in gas shale. J Unconventional Oil and Gas Resources 7:33-48

EPA (US Environmental Protection Agency) (2015) Review of state and industry spill data: Characterization of hydraulic fracturing-related spills. EPA/601/$-14/001

Fisher K, Warpinski N (2011) Hydraulic fracture-height growth: real data. Paper SPE presented at the Annual Technical Conference and Exhibition, Denver, Colorado. DOI:10.2118/145949 – MS.

Flewelling SA, Sharma M (2013) Constraints on upward migration of hydraulic fracturing fluid and brine. Groundwater, doi:10.1111/gwat.12095.

Fountain JC, Jacobi RD (2000) Detection of buried faults and fractures using soil gas analysis. Environ Eng Geosci 6(3):201-208

Gassiat CT, Gleeson T, Lefebvre R, McKenzie J (2013) Hydraulic fracturing in faulted sedimentary basins: Numerical simulation of potential contamination of shallow aquifers over long time scales. Wat Resour Res 49:8310-8327, doi:10.1002/2013WR014287.

Goss G, Alessi D, Allen D, GEhman J, Brisbois J, Kletke S, Sharak AZ, Notte C, Thompson DY, Hong K, Junes VRC, Neto WBG, Prosser C (2015) Unconventional wastewater management: a comparative review and analysis of hydraulic fracturing wastewater management practices across four North America basins. Prepared for Canadian Water Network. University of Alberta.

Haluszczak LO, Rose AW, Kump LR (2012) Geochemical evaluation of flowback brine from Marcellus gas wells in Pennsylvania, USA. Appl Geochem 28: 55-61

Hammack, R., W. Harbert, S. Sharma, B. Stewart, R. Capo, A. Wall, A. Wells, R Diehl, D. Blaushild, J. Sams, and G. Veloski. 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.

Harrison SS (1983) Evaluating system for ground-water contamination hazards due to gas-well drilling on the glaciated Appalachian Plateau. Ground Water 21(6):689-701

Jackson RB, Vengosh A, Darrah TH, Warner NR, Down A, Poreda RJ, Osborn SG, ZhaoK, Karr JD (2013) Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. Proc Natl Acad Sci, USA 110(28):11250-11255

Kissinger A, Helmig R, Ebigbo A, Class H, Lange T, Sauter M, Heitfeld M, Klunker J (2013) Hydraulic fracturing in unconventional gas reservoirs: risks in the geological system, part 2. Env Earth Sci, doi 10.1007/s12665-013-2578-6

Kohl CAK, RC Capo, BWStewart, AJ Wall, KT Schroeder, RW Hammack, GD Guthrie (in press) Strontium isotopes test long-term zonal isolation of injected and Marcellus formations water after hydraulic fracturing. Environ Sci Technol doi/10.1021/es501099k

Lange T, Sauter M, Heitfeld M, Schetelig K, Brosig K, Jahnke W, Kissinger A, Helmig R, Ebigbo A, Class H (2013) Hydraulic fracturing in unconventional gas reservoirs: risks in the geological system part 1. Environ Earth Sci DOI 10.1007/s12665-013-2803-3.

Lauer N, Vengosh A (2016) Age dating oil and gas wastewater spills using radio isotopes and their decay products in impacted soil and sediment. Environ. Sci. Technol. Lett. 3:205-209. Doi:10.1021/acs.estlett.6b00118.

Lefebvre R (2017) Mechanisms leading to potential impacts of shale gas development on groundwater quality. Wiley Interdisciplinary Reviews: Water 4(1): E1188

Llewellyn GT (2014) Evidence and mechanisms for Appalachian Basin brine migration into shallow aquifers in NE Pennsylvania, USA. Hydrog J DOI 10.1007/s10040-014-1125-1

Llewellyn GT, Dorman F, Westland JL, Yoxtheimer D, Grieve P, Sowers T, Humston-Fulmer E, Brantley SL (2015) Evaluating a groundwater supply contamination incident attributed to Marcellus Shale gas development. Proc Natl Acad Sci 112(20):6325-6330, doi 10.1073/phas.1420279112.

Molofsky LJ, Connor JA, Wylie AS, Wagner T, Farhat SK (2013) Evaluation of methane sources in groundwater in northeastern Pennsylvania. Groundwater 51(3):333-349, Doi:10.1111/gwat.12056

Myers T (2012) Potential contaminant pathways from hydraulically fractured shale to aquifers. Ground Water 50(6): 872-882 doi: 10.1111/j.1745-6584.2012.00933.x

Olmstead SM, Muehlenbachs LA, Shih J,Chu Z, Krupnick AJ (2013) Shale gas development impacts on surface water quality in Pennsylvania. Proc Natl Acad Sci, USA 110(13):4962-4967

Osborn SG, Vengosh A, Warner NR, Jackson RB (2011a) Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proc Natl Acad Sci, USA 108:8172-8176

Patterson LA, Konschnik KE, Wiseman H, Fargione J, Maloney KO, Kieseck J, Nicot J, Baruch-Mordo S, Entrekin S, Trainor A, Saiers JE (2017) Unconventional oil and gas spills: Risks, mitigation priorities, and state reporting requirements. Env Sci Tech *****

PDEP (Pennsylvania Department of Environmental Protection) (2017) Road-spreading of brine for dust control and road stabilization. 800-FS-DEP1801.

Person M, L Baumgartner (1995) New evidence for long-distance fluid migration within the Earth's crust. Reviews of Geophysics, Supplement p 1083-1091.

Ripendra A (2016) Hydraulic Fracturing and Its Potential Impact on Shallow Groundwater, Chapter 2 in Emerging Issues in Groundwater Resources.

Rowan EL, MA Engle, TI Kraemer, KT Schroeder, RW Hammack, MW Doughten (in press) Geomechanical and isotopic evolution of water produced from Middle Devonian Marcellus Shale gase wells, Appalachian Basin, Pennsylvania. AAPG Bulletin, doi: 10.1306/07071413146.

Shipton ZK, JP Evans, D Kirchner, PT Kolesar, AP Williams, J Heath (2004) Analysis of CO2 leakage through "low-permeability" faults from natural reservoirs in the Colorado Plateau, southern Utah. In: Baines, SJ, RH Worden (eds.) *Geologic Storage of Carbon Dioxide*. Geological Society, London, Special Publications 233, 43-58.

Skalak KJ, Engle MA, Rowan EL, Jolly GD, Conko KM, Benthem AJ, Kraemer TF (2014) Surface disposal of produced waters in western and southwestern Pennyslvania: Potential for accumulation of alkali-earth elements in sediments. Int J Coal Geol 126:162-170. Doi 10.1016/j.coal.2013.12.001

Taylor LE (1984) Groundwater Resources of the Upper Susquehanna River Basin, Pennsylvania. Pennsylvania Geological Survey, Harrisburg PA.

Taherdangkoo R, Tatomir A, Taylor R, Sauter M (2017) Numerical investigations of upward migration of fracking fluid along a a fault zone during and after stimulation. Energy Procedia 125:126-135.

U.S. Environmental Protection Agency (EPA) (1987) Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy, U.S. Environmental Protection Agency, Washington, DC.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE (1980) The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37(1):130-137. Doil 10.1139/f80-017.

Vidic RD, Brantley SL, Vandenbossche JM, Yoxtheimer D, Abad JD (2013) Impact of shale gas development on regional water quality. Science 340, 1235009 (2013). DOI: 10.1126/science.1235009

Warner NR, Jackson RB, Darrah TH, Osborn SG, Down A, Zhao K, White A, Vengosh A. 2012a. Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania. Proceedings of the National Academy of Sciences pnas.1121181109

Wilson MP, Worrall F, Davies RJ, Hart A (2017) Shallow aquifer vulnerability from subsurface fluid injection at a proposed shale gas hydraulic fracturing site. Water Resour Res 53(11): 9922-9940

Zhang, L., N. Anderson, R. Dilmore, D.J. Soeder, and G. Bromhal. 2014. Leakage detection of Marcellus shale natural gas at an upper Devonian gas monitoring well: A 3-D numerical modeling approach. Environmental Science and Technology 48:10795-10803, doi:10.1021/es501997p.

Review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations

Prepared for the
Delaware Riverkeeper Network
Bristol, Pennsylvania

Prepared by
Glenn C. Miller, Ph.D.
Consulting Environmental Chemist
Reno, NV

March 20, 2018

Introduction: This document represents a review of the Draft Delaware River Basin Commission's Regulations on Hydraulic Fracturing in Shale and Other Formations, specifically regarding the concerns surrounding management and potential discharge of brines derived and released during and after fracturing operations in the Delaware River Basin or at locations outside of the Basin.

I have examined many of the chemical and toxicological issues, particularly related to potential treatment and discharge into the Delaware River Basin of waters associated with hydraulic fracturing, primarily produced and flowback (formation) water. This issue has confronted the Delaware River Basin Commission for several years now, and I appreciate the thought that has gone into these regulations. I feel strongly that, due to the chemical complexity of these highly contaminated waters, the best solution is to simply remove the option of disposal of any hydraulic fracture (HF) associated waters to any surface water in the Delaware Basin. The areas of the river designated by the Commission as Special Protection Waters (the nontidal river) cannot maintain adopted or proposed water quality standards nor meet the "No measurable change" requirement enforced by the Commission if the waters produced by hydraulic fracturing are discharged to the Basin's waterways, particularly if the HF waters are not treated to remove metals, salts and norm. The region below Philadelphia already receives a variety of discharges, and potentially adding a major load of a complicated array of contaminants from HF water should simply be prohibited. The industry is currently reusing these contaminated waters in other HF gas wells, and/or disposing of them in deep receiving wells where the geological conditions allow deep well injection. This latter option is presently being used, and will likely be used in the future.

The following comments should be considered.

A. The flowback and produced water that flows back up the wells following hydraulic fracturing is heavily contaminated, primarily with the Marcellus formation contaminants. The produced brines that are released during gas production are complex and contain a variety of problematic contaminants and represent a serious chemical contamination potential.

The Commission clearly recognizes the problems with contaminants in HF waters, particularly in the non-tidal portions of the Delaware River. However, further efforts are required for understanding <u>all</u> of the contaminants in the flowback and produced water, their management and disposal. Four problematic components of the flowback water and produced brines include (1) the inorganic salts (including bromide), metals and metalloids, (2) the radioactive component (NORM), (3) the organic substances (from the hydrocarbon formation) and, (4) the chemical additives that increase the efficiency of gas recovery.

1. ***Salts and inorganic constituents in the formation water, that are brought to the surface both as flowback and as production brines*:** The largest mass component of the formation water is salts and other inorganic constituents. The concentration of these constituents varies widely, as does their toxicity. Because the geological formation waters are proposed to be collected and temporarily stored in closed systems, disposal of these large volumes of water is, in my opinion, the largest problem with their management. The Commission clearly understands the problems with management of this water, and, in particular the discharge of high TDS water into receiving waters and recognizes that these brines will need to be regulated as industrial wastewater.

   The associated EPA study (EPA, 2016) on management of HF water shows that produced waters containing the formation water are variable in chemical composition, but include not only simple salts (e.g. sodium, potassium, chloride, bromide, sulfate, fluoride etc.) but also a variety of metals with varying frequency (cadmium, mercury, cobalt, nickel) and metalloids (arsenic, selenium, boron). Some of the constituent concentrations are very high, particularly sodium chloride, which has a mean concentration of on the order of 10% by weight. Some samples had over 30% by weight of simple salts plus other contaminants. The extreme contamination of these wastewaters, and the high variability of contaminant levels, make these waters complicated for treatment and potential reuse, as well as for tracking and disposal. If improperly managed and released to surface or groundwater, potentially severe contamination is likely. In particular, if this contaminated water intercepts domestic groundwater or surface water used as a drinking water source, the potential exists that these sources of water may need to be removed as a domestic source. While the proposed regulations effectively may not allow discharge of these waters into a surface stream that can be used as drinking water, that appears to not be the case for the more saline portions of the Basin.

   While recognizing the problems with management of this water, the Commission fails to clearly state how this water will be either disposed in a manner that protects human health and the environment, or otherwise treated to remove the contaminants. While a range of alternatives potentially exist, effectively none of these is likely to be accomplished in even a centralized waste treatment facility, and simply eliminating these waters from the Basin is the prudent alternative.

   A particular constituent that has been problematic in Pennsylvania waters receiving partially treated hydraulic fracturing water is bromide. When water is taken in to be treated as a drinking water, normal disinfection processes (chlorine and chloramine) convert bromide ion to bromide radical, which reacts with naturally occurring organic matter to produce the probable carcinogenic brominated trihalomethanes (THM). Because of the higher molecular weight of the brominated trihalomethane, the drinking water can violate drinking water for trihalomethanes (Chowdhury, et al., 2010; EPA, 2016) Use of ozone as a disinfectant can generate bromate, a known carcinogen (Fellet, 2014).

2. ***Radioactive Substances (NORM):***
The Commission also certainly recognizes the issues associated with management of NORM that comes to the surface either in the flowback or the production brines. However, similar to the salt problem discussed above, no indication on how treatment to remove these materials will be conducted.

Examples of NORM concentrations are presented from flowback in the EPA study (EPA, 2016).

The level of radioactivity as gross alpha is very high, from about 18,000 pCi /L to 123,000 pCi/L. The drinking water standard is 15 pCi/L (gross alpha).

What is to be done with these waters, and what is to be done with the residual NORM, if it is removed from the produced water and the flowback water? Dilution of the brines to a drinking standard of 15 pCi/L (gross alpha) will require 1000x to 10,000x dilutions, and is unlikely to be acceptable in nearly all jurisdictions, particularly when the components that are causing the radioactivity are not specified.

Ultimately, these radioactive materials will need to be removed offsite. Where will these radioactive materials be disposed, and will they be included with the very large tonnage of salts that results from an evaporation-crystallization treatment, or will they be separated into a metal/radioactive fraction by some (unknown?) chemical precipitation process? These issues are critical for an analysis of the potential impacts of management of these materials, and the lack of a thorough analysis presents a serious problem when assessing the risk of these substances. There is effectively no discussion of how these materials will be disposed, other than a general suggestion that they would be "treated" in a centralized treatment facility. In fact, there is no demonstrated economic and chemically efficient method for disposal of these wastes which is why most of this waste is transported to a deep well disposal site.

3. ***Hydrocarbons present in the formation water:*** Hydrocarbons present in the flowback and produced water are characteristic of fuel hydrocarbons, and are represented by (a) compounds that, in some cases, are carcinogenic (e.g. benzene, benzo(a)pyrene), (b) common solvents (e.g. toluene, ethylbenze), and (c) the primary fuel components of natural gas, particularly methane. But, these components are only part of the mix that is contained in fracking water. Other components include heterocyclic amines, sulfur (odor) containing compounds, and an array of unknown compounds that have not

yet been identified from specific wells. The characterization of these constituents before and after treatment has not been completed. Without knowing what these chemicals are, and the toxicity of each of them, it is difficult to know how to treat them. The associated risk is primarily ecological, and, again, simply eliminating discharge of HF waters is the safe option.

4.Hydraulic fracturing additives: The range of hydraulic fracturing additives is very large, and difficult to assess from a risk perspective, since the list is almost certainly incomplete, specific information on the chemicals is lacking, and the specific rate of usage is not offered. Thus, not knowing the composition of the specific additives and the amounts provides effectively no basis for estimating the risk of these components on the biota of the receiving water. A mere laundry list of these components does not meet requirements for analysis of their potential impacts. The list is so long, and the data on each component so meager, that it falls far short of an analysis of risk. Additionally, many additives used are given proprietary trade names, and while the regulators may have information on the constituents in those products, the public does not, and thus the public cannot legitimately understand the risk of these products. Additionally, treatment of those proprietary compounds, even in a CWT, is not understood and ultimate disposal in a surface water constitutes a risk that can be avoided entirely by requiring deep well disposal in a permitted facility outside of the Basin.

B. Permissible treatment of the flowback and the produced water is not well defined. It is unclear how the post-treatment residual salts and radioactivity will be managed. There does not appear to be any complete treatment of these waters that will allow discharge of the water in any surface water of the Delaware River Basin.

In my opinion, there are no treatment options that can remove the contaminants in a cost effective manner, and suggest that until such a process is developed, discharge of HF water should simply be banned within the basin to avoid the unreasonable risk of the contamination and loss of drinking water resources. This is particularly the case for drinking water sources, but also for lower basin waters, primarily associated with ecological risk. Some of the membrane processes (e.g. reverse osmosis, nanofiltration) may meet the standards in some cases for a portion of the water, although the reject water will still need to be disposed out of the basin and will contain higher concentrations of all of the contaminants. Effectively, there is no reasonable cost alternative to simply transporting the HF waters to regions where deep well disposal is permitted, which is the way those waters are being managed to date.

The methods for treatment of the water for discharge to a surface water are not considered, and how specific requirements for discharge could be met by various treatment processes (e.g. membrane, ion exchange or evaporative processes) are not mentioned. The residual contaminants removed by evaporative or membrane processes, and thus concentrated to form even more contaminated water, were not discussed, other than to indicate that the residual salts, or concentrated brine will require "further treatment or disposal". For flowback or brine containing 7% (70,000 mg/L) salts, upwards of 300 tons of salts will exist in every million gallons of water, plus the concentrated NORM as well as a portion of the hydrocarbons. The source of the alpha emitters also will need to be identified. If, as is suspected, polonium is present in the flowback water, it represents an additional management burden of the flowback and produced water.

C. The best option is simply to prohibit storage or treatment of HF water in the Delaware River Basin entirely. Odors are a particular problem for management/storage/treatment of HF waters, and a variety of chemicals are present in hydrocarbon formations that can present a serious odor problem, which can be both a serious human health issue and can affect the quality of life of persons living near these sites. A very common, but toxic, constituent is hydrogen sulfide, characterized by a rotten egg smell. Other organic sulfides can also be present, including a variety of alkyl sulfides. Odors are very difficult to regulate, due to the vagaries associated with odor detection, acclimation, and differential effects on different persons. The severity of an odor is in the nose of the beholder. Odors are particularly bothersome to persons living downwind, and storage of HF waters in the Basin can very likely lead to complaints, which should be taken seriously.

Spills are another problem with HF waters, and the EPA (EPA, 2016) has noted spills occurring throughout the HF industry. These spills can be minor or major, but each spill has the potential to contaminate surface and groundwater, and will likely sterilize the ground that it contaminates.

Banning management of these waters in the Basin will substantially lessen the impact of HF waters on residents of the basin from both spills and odors.

D. Tidal versus Non-Tidal facilities:

From my read of the proposed regulations, it appears that disposal of HF waste water will be effectively prohibited through even a centralized water treatment (CWT) facility in areas where the receiving water can potentially be a drinking water, and in the areas designated as Special Protection Waters. With a TDS limit of 500 mg/L limit, the salt load in these HF waters would effectively preclude any reasonable treatment (other than a membrane treatment) for discharge.

However, on a closer reading this may not be the case for the tidal waters that have a higher TDS limit. The language in the 440.5(f) section contain words that allow a broad discretion on whether a facility can be sited in the saltier sections of the River, with discretionary terms such as "mixing zone" or "or a concentration established by the Commission that is compatible with designated water uses and stream quality objects".

Existing discharges to the lower portion of the basin, from POTW and other industrial discharges already provide a source of contaminants that are of concern. While the Delaware River water quality has improved through dedicated efforts of the Commission, the lower stretch of the Delaware River Basin already receives discharges from other industries. While a pure sodium chloride discharge may not have a major negative impact on the biota of the Basin, the other constituents in HF water, including organic compounds and the radioactivity can still provide an unacceptable risk to the ecological integrity of the Basin.

Conclusion: There is no compelling reason to allow any storage/treatment/discharge of HF water in the Delaware River Basin, and many reasons why this presents an unacceptable risk to the region. With the very large efforts that have been implemented to improve and protect the Basin, adding an additional risk by allowing HF waters in the Basin is unwise and will set back the success that has been realized to date. Production of natural gas near the Basin requires consideration of a variety of economic factors, and one of them should be that the production entities need to factor in the costs of reuse of these waters in other HF wells, or transport of these highly contaminated water to a permitted disposal well facility, which is presently the current method of disposal of these wastes. The disposal of these waters should not be placed on the communities who enjoy the values of the Delaware River Basin that presently exist, or the 15-17 million people who rely on the Delaware River Watershed for their drinking water.

References

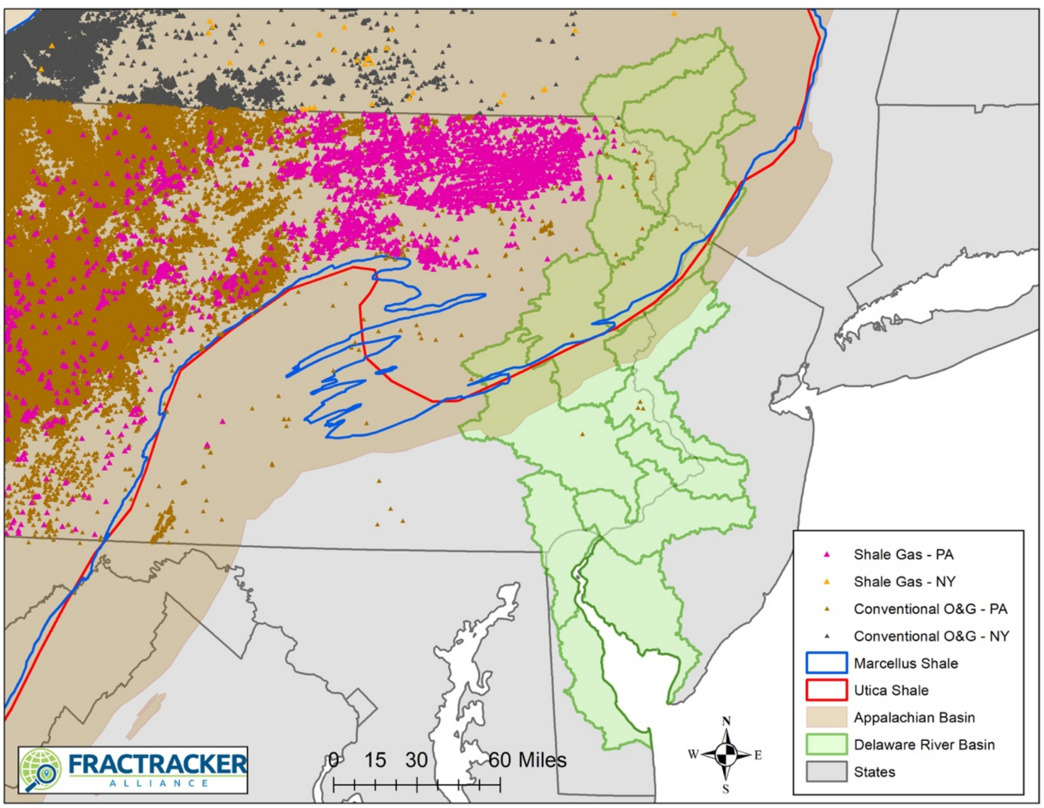
Chowdhury, S., P. Champagne, and J. McLellen, (2010) "Investigating effects of bromide ions on trihalomethanes and developing model for predicting bromodichlormethane in drinking water" Water Research, 44:2349-59)

EPA, (2016) "Technical Development for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category" US EPA Office of Water, Washington, D.C. EPA-820-R-16-003

Fellet, Melissae, (2014) "Fracking Wastewater Could Encourage Formation of Toxic Compounds During Drinking Water Disinfection" Chemical and Engineering News, September 23, 2014,

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

March 20, 2018 / FracTracker Alliance Issue Paper / Main Author: Matt Kelso



Author:
FracTracker Alliance
1845 Market St, Ste. 204,
Camp Hill, PA 17011
(717) 303-0403
info@fractracker.org
www.fractracker.org

Prepared for:
Delaware Riverkeeper Network
925 Canal St Suite 3701
Bristol, PA 19007
drn@delawareriverkeeper.org
www.delawareriverkeeper.org

Executive Summary

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

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

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

Acknowledgements

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

Delaware Riverkeeper Network provided the funding for this research.

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

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

Summary of the O&G Industry in the Delaware Basin

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

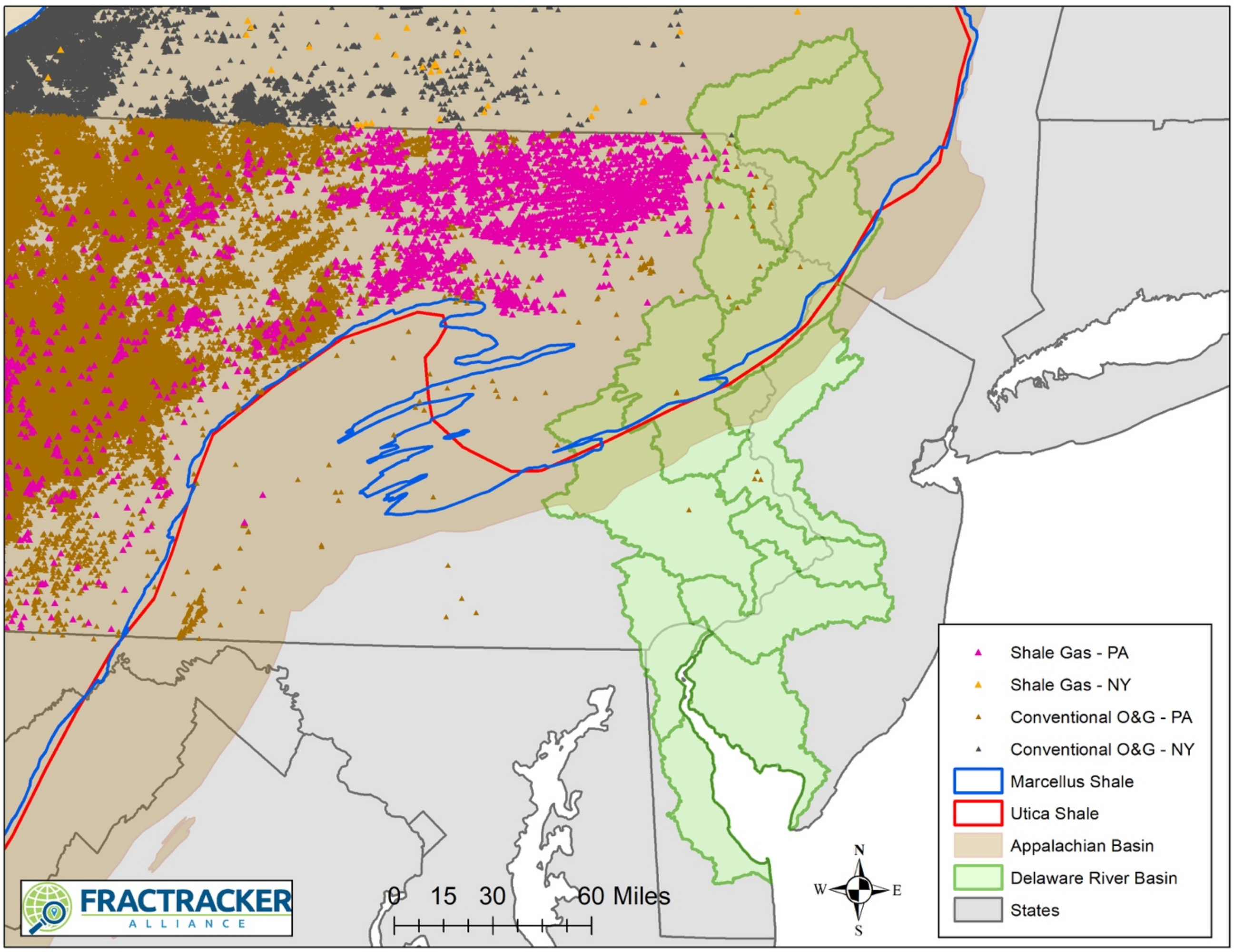


Figure 1. O&G resources and activity near the Delaware River Basin. If the New York ban and DRBC de facto moratorium were lifted, the potential impact of unconventional drilling on the Delaware River Basin could be substantial.

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

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

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

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

Water Usage

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

---

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

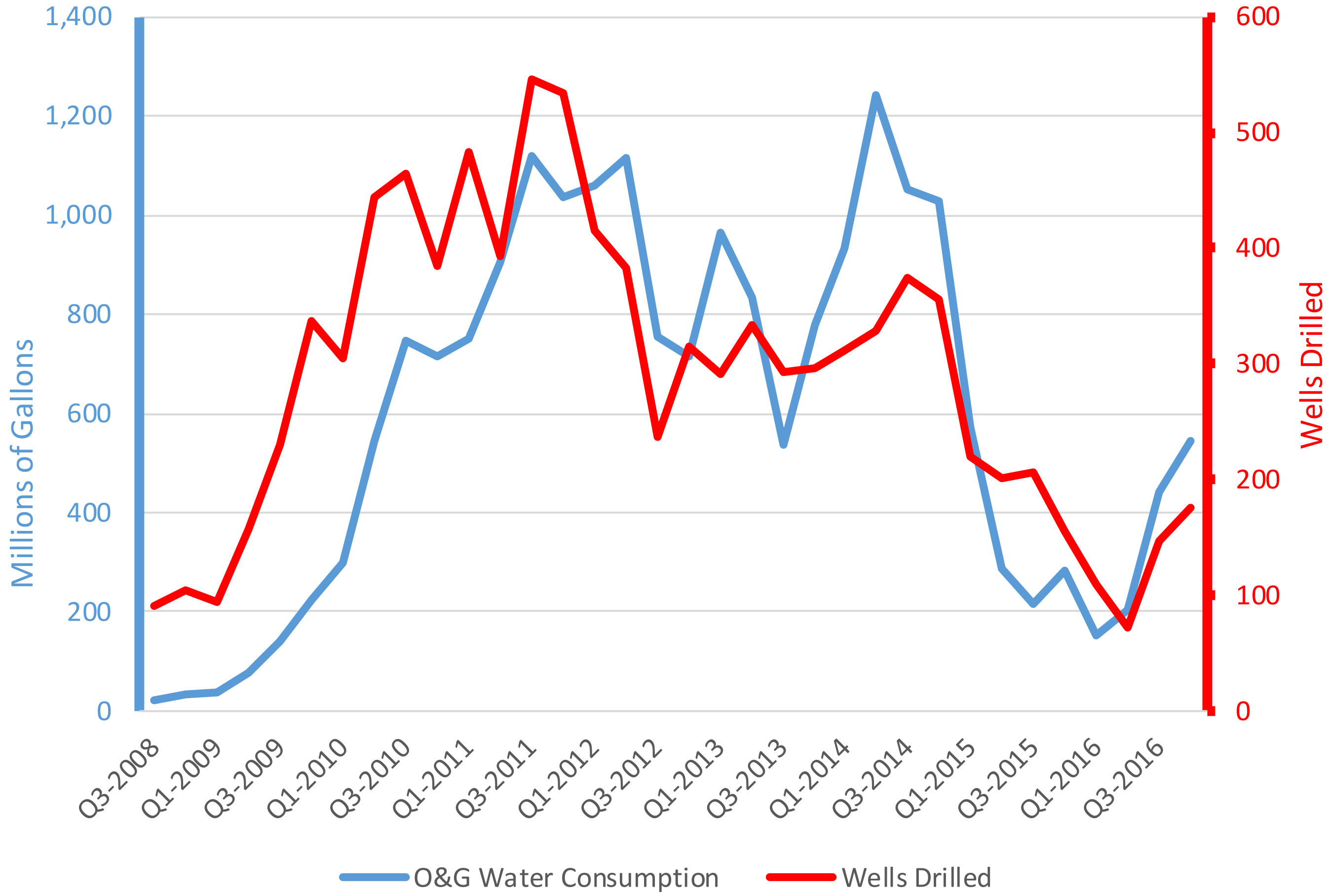


Figure 2. PA Drilled Wells and O&G Water Consumption in the Susquehanna River Basin over time

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

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

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

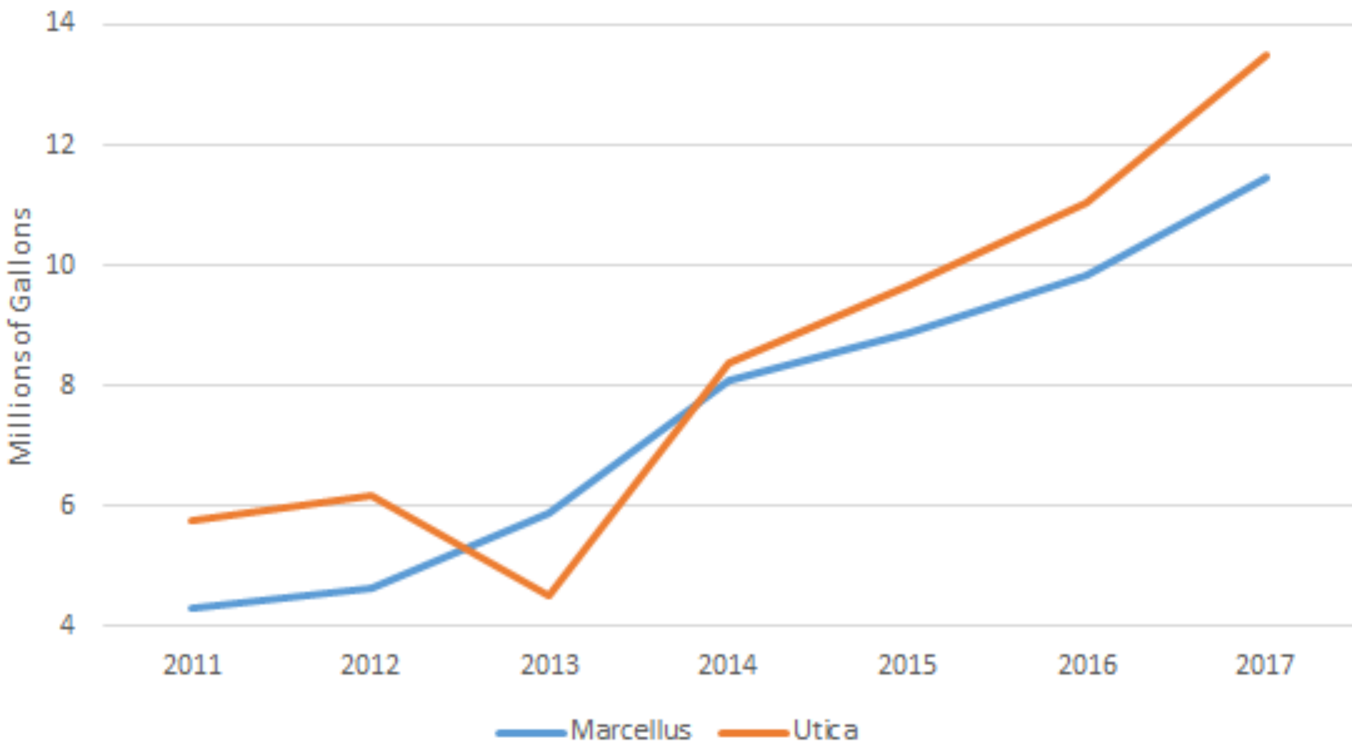


Figure 3. Water use per wells in PA based on industry data submitted to FracFocus

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

---

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

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

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

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

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

Year	Wells Drilled	Average Water	Estimated Water
2011	1,959	4,340,524	8,503,086,609
2012	1,350	4,640,585	6,264,790,136
2013	1,214	5,838,822	7,088,329,348
2014	1,371	8,112,099	11,121,687,702
2015	784	9,089,367	7,126,063,393
2016	504	10,058,239	5,069,352,370
2017	539	11,590,975	6,247,535,763
Total	**7,721**	**53,670,611**	**51,420,845,321**

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

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

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

Dealing with Waste

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

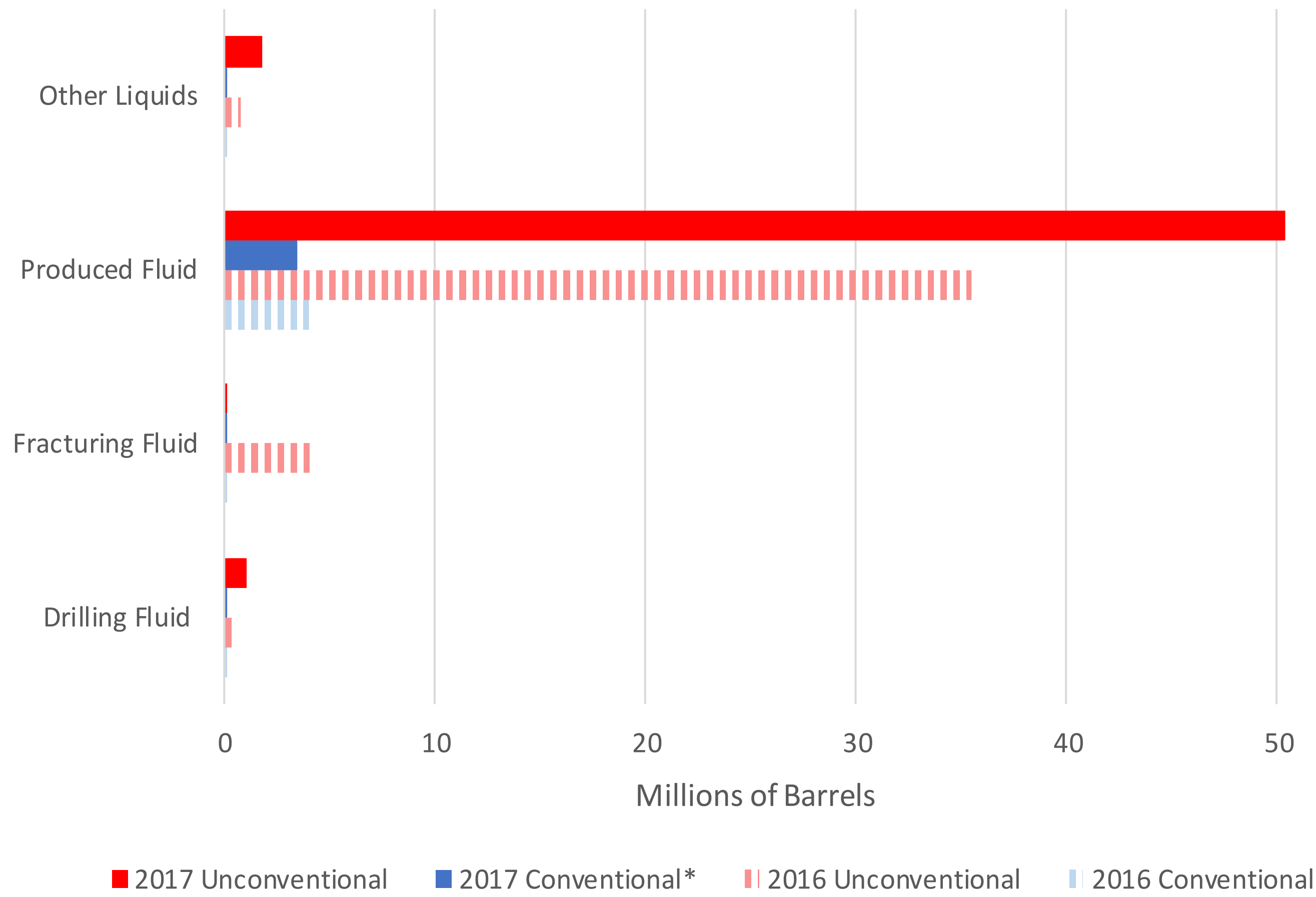


Figure 4. 2016-17 Liquid O&G Waste in Pennsylvania[11] (in millions of barrels). Totals for some waste types do not show on the scale of this chart, but are shown in Table 2, below.

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

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

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

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

* We suspect the conventional waste report was substantially incomplete at the date downloaded.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

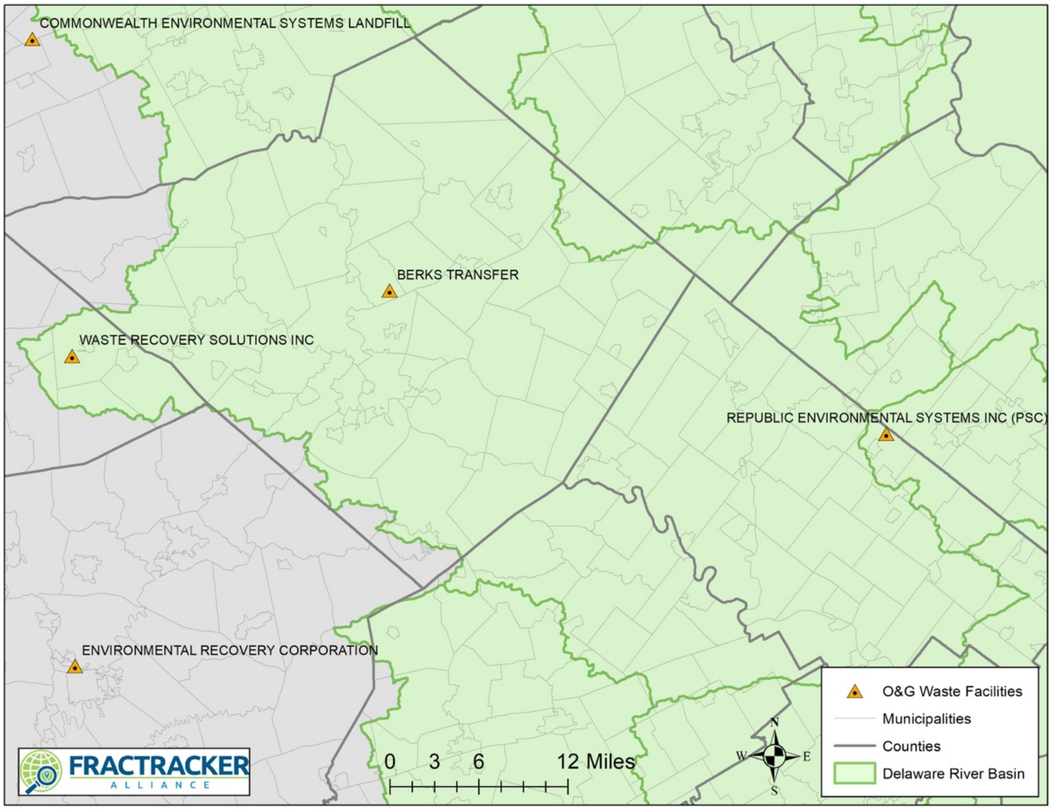


Figure 5. Map of facilities in Pennsylvania's section of the Delaware River Basin that accept solid oil and gas waste for disposal

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

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

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

Conclusion

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

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

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

[21] Matheny K. (2014). Michigan landfill taking other states' radioactive fracking waste. Lansing State Journal. https://www.lansingstatejournal.com/story/news/local/michigan/2014/08/19/michigan-takes-in-radioactive-sludge/14275129/
[22] PA DEP. Spud Report. http://www.depreportingservices.state.pa.us/ReportServer?/Oil_Gas/Spud_External_Data
[23] PA DEP. Oil and Gas Compliance – Report Viewer. http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Compliance
[24] Hanson L, Habicht S, Faeth P. (2016). Potential Environmental Impacts of Full-development of the Marcellus Shale in Pennsylvania - Map Set 1: Development Projections. CNA. https://www.cna.org/cna_files/pdf/Maps1_WellProjections.pdf

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

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

insights empowering action

1845 Market St, Ste. 204,
Camp Hill, PA 17011
(717) 303-0403
info@fractracker.org
www.fractracker.org
@FracTracker

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

Analysis: Matt Kelso, Manager of Data and Technology, FracTracker Alliance
Layout and Editing: Samantha Rubright, DrPH, CPH, Manager of Communications and Partnerships, FracTracker Alliance

Appendix A

Methodology & Data Download

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

Methodology

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

Data Download

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

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

Comments on Proposed Regulations

of

The Delaware River Basin Commission

Concerning

High Volume Hydraulic Fracturing to Produce Oil and Gas

Prepared for: **Delaware Riverkeeper Network**
925 Canal Street
Bristol, Pennsylvania 19007
215-369-1188 www.delawareriverkeeper.org

Prepared by: **Schmid & Company, Inc., Consulting Ecologists**
1201 Cedar Grove Road
Media, Pennsylvania 19063
610-356-1416 www.schmidco.com

19 March 2018

Background

The Delaware River Basin Commission (DRBC) is proposing to amend its *Special Regulations* and its *Administrative Manual Rules of Practice and Procedure* in regard to the extraction of petroleum hydrocarbons using technology known as high volume hydraulic fracturing (HVHF or fracking) that both consumes and contaminates large volumes of water. In addition, changes are proposed regarding the regulation of wetlands and of leachate from solid waste disposal facilities. The Delaware Riverkeeper Network commissioned this commentary as part of its submission pursuant to the DRBC's 30 November 2017 request for comments from the public on the proposed regulations.

The DRBC is an interagency entity formed in 1961 by compact between the States of Delaware, New Jersey, New York, and Pennsylvania (Figure 1)[1] and the federal government to manage water resources jointly in the Delaware River basin (the Basin). The Basin includes all or portions of 42 counties (Figure 2) and all or portions of 838 municipalities.

The DRBC has designated part of its jurisdictional area as Special Protection Waters (Figure 3), and it has established water quality criteria for them. Special Protection Waters drain approximately 4.4 million acres of land and are located within the northern half of the DRBC area. The distribution of Special Protection Water drainage areas in the Basin is as follows (none is in Delaware):

Pennsylvania	=	50%
New York	=	35%
New Jersey	=	15%

Basin water resources are used by more than 15 million people. The quantity of water available in the Basin varies over time, and shortages occur during periods of drought. Water quality varies across the Basin in large part in response to human activities but also as a result of natural environmental factors. The streams and groundwaters of the Basin have a limited capacity to assimilate polluting substances in discharged wastewater while maintaining designated uses as suitable sources of potable water, aquatic life support, and other human purposes. The DRBC traditionally has focused on large-scale activities that affect large quantities of water, rather than the activities of individual householders.

DRBC proposes to amend certain of its regulations at 18 CFR 401 and add a new part 440 in order (1) to prohibit permanently the use of fracking to extract oil and gas within the Basin, (2) to regulate the export of any freshwater from the Basin to be used for fracking elsewhere, (3) to regulate the import of any oil and gas wastewater into the Basin from fracking elsewhere, (4) to change its procedure for authorizing activities affecting wetlands,

[1] Figures are displayed at the end of the text.

and (5) to change its regulations to address specifically the leachate from solid waste disposal facilities rather than the landfills and other facilities themselves. Since 2010 DRBC has maintained a moratorium on fracking for shale gas production within the Basin. There is also a ban on fracking in effect at present in New York State and in several of its municipalities aimed at protecting public health and the environment.

DRBC specifically requested comments on the effects its proposed rules may have on

- Water availability,
- Control and abatement of water pollution,
- Economic development,
- Conservation and protection of drinking water supplies,
- Conservation and protection of aquatic life,
- Conservation and protection of water quality in Special Protection Waters, and
- Protection, maintenance, and improvement of water quality and quantity basinwide.

Schmid & Company professionals have decades of experience applying their expertise in wetlands, stream protection, and environmental impact assessment throughout the Basin and the mid Atlantic region. These comments draw upon experience gained from our diverse project work on behalf of environmental permit applicants, for conservation groups, and in direct support of regulatory agencies at the federal, State, and municipal levels.

Fracking of Hydrocarbon Resources

Geological formations known as the Marcellus Shale and the even deeper Utica Shale underlie the northern 40% of the Delaware River Basin in eastern Pennsylvania and southern New York, typically 7 to 10 thousand feet below the present land surface. They constitute the largest petroleum-producing deposits in the United States. Organic remains slowly accumulated in the beds of shallow seas as these shales were laid down during the Devonian period some 400 million years ago. As the Appalachian Mountains rose in response to colliding tectonic plates, the organic deposits were buried and altered to form hydrocarbons deemed useful today for industrial purposes.

The northern portion of the Marcellus Shale underlies portions of Pennsylvania, Ohio, West Virginia, Virginia, Maryland, and New York (Figure 4). Of the total area of Marcellus Shale reserves, only 5% underlies the DRBC area. Within the Basin, Marcellus Shale is located only in Pennsylvania and New York; none is within New Jersey or Delaware. Most sections of the Basin underlain by Marcellus Shale reserves are designated Special Protection Waters (Figure 5). In New York, almost all (98%) of the area designated Special Protection Waters is underlain by Marcellus Shale reserves. In Pennsylvania, approximately two-thirds (67%) of the area designated Special Protection Waters is underlain by Marcellus Shale reserves.

Until the present century the petroleum trapped in these “tight” Marcellus and Utica Shale formations was deemed not economically recoverable using traditional vertical wells that had been developed to tap oil and gas held in sandstone and carbonate rocks. During the past decade innovative combinations of drilling and hydraulic fracturing technology have been employed to extract natural gas and other hydrocarbons from these formations in Pennsylvania and other States. Depending on the worldwide market for fossil fuels, industry may seek to exploit the natural gas reserves long trapped beneath the Basin.

Current unconventional technology employs mixtures of water, sand (the most common proppant for holding cracks open), and chemicals injected under high pressure by diesel-powered pumps to break apart shale rocks so that long-trapped natural gas and other hydrocarbons can make their way to the surface through bored wells. Drilling technology now allows the advance of borings that extend thousands of feet deep and thousands of feet horizontally from the drill rig. To be classed by DRBC as HVHF, a well must use more than 300,000 gallons of water during its development. Each unconventional well currently makes use of 4 to 10 million gallons of water each time it is fracked, and the volumes of water needed increase significantly as well bores become longer. The typical 8 to 10-acre well pad may accommodate as many as a dozen wells. Most of that water remains in the underground strata; the rest returns as “produced” wastewater to the surface. Much of the produced water returns during the weeks shortly after the hydraulic pressure is released, but lesser flows continue throughout the life of each well.

The water necessary for fracking is obtained from surface sources or occasionally from wells in groundwater aquifers that are shallow relative to the target shale deposits. Near-surface aquifers are linked with surface waters, from which they can receive both replenishment and pollutants. The quantities of water required for fracking are large enough that they can deplete local streams and groundwater aquifers, especially during periods of drought. Such quantities of water require hundreds of large trucks for transport, and in some cases are moved by pipelines laid above or below ground. The wastewater produced at well pads contains high concentrations of harmful chemicals that are technically difficult and costly to separate from the water itself.

Explosives and frackwater pressure open existing cracks and create new fractures in the rock layers surrounding each well bore. Much of the fracking fluid binds to the rocks underground. Drillers store nearby in ponds or containers the produced water that returns to the surface after hydraulic pressure is released and reuse it to frack multiple wells; the remainder is transported long distances to deep injection wells where it is intended to be isolated permanently, far below potable groundwater aquifers. Relatively little produced water is treated for release to surface streams and rivers. Hence the use of water for fracking is deemed by DRBC to be a “consumptive” use. More than 90% of frackwater would be lost to natural recycling within the Basin. This contrasts sharply with most other industrial and municipal uses of water within the Basin, more than 90% of which volume returns to the Basin’s water cycle after human use and treatment to remove pollutants.

Chemicals typically are added to frackwater to reduce friction and prevent bacterial growth. About 1,000 kinds of substances have been added to the water as drillers seek to optimize their recovery of energy-producing hydrocarbons. The mixes of added chemicals, together with various salts plus organic and naturally occurring radioactive compounds extracted from the shale by the frackwater, render produced water toxic to people, animals, and plants in the event that it is released or spilled into the environment. Frackwater must be transported primarily by truck to and from well sites, where it is stored temporarily in open basins or closed containers. Containment capacity must be provided at each well pad yielding gas to store the continually produced wastewater after drilling stops. Fractured rock layers near well bores can intercept natural faults or abandoned wells through which the pressurized fluid can escape unintentionally. Escaped or leaking frackwater contaminates groundwater aquifers and the land surface as it flows by gravity into wetlands and streams. Unscrupulous operators may spread frackwater on roads as concentrated brine intended to reduce dust or to melt snow and ice. Several hundred tons of mineral salts are produced in the brine from an individual HVHF well.

The dramatic results of unintended leaks from unconventional gas wells have received wide publicity when invisible and odorless methane (natural gas) renders the tap water from home wells flammable. So have catastrophic explosions of high-pressure pipelines transporting natural gas and other hydrocarbons from wells to users. Other leaked or spilled contaminants can impart undesirable color or odor or taste or poisons to drinking water. Some of the contaminants present in frackwater do not break down readily into benign compounds; salts are not removed by normal publicly owned sewage treatment systems. Other pollutants can be transformed in the environment into low, difficult-to-detect, but still toxic concentrations of compounds linked to genetic mutations and cancers. Routine drinking water treatment can yield unhealthy concentrations of brominated hydrocarbons that originated in frackwater in public water supplies downstream from wastewater treatment plants. Hence produced frackwater can pose serious but hard-to-manage risks, either transient or permanent, to public health and to the environment. Yet information regarding the proprietary mix of chemicals injected at each well and produced by dissolution of in-ground substances is seldom collected or disclosed to the public, making human health symptoms difficult to diagnose and treat by health professionals.

Some of the produced frackwater pollutants that affect water quality already are found in the environment as a result of natural conditions and/or legacy human activities that formerly extracted oil and coal. The locations of many thousands of abandoned wells are unknown in Pennsylvania. Existing data on old wells are incomplete, and drillers may miss such features when planning new wells. Background concentrations of pollutants are not required to be documented in nearby wells and streams prior to HVHF well installation. Spills and leaks are not always reported, and required agency inspections may provide inadequate and infrequent oversight. As a January 2018 white paper from PADEP addressing proposed reforms of its permitting stated,

> DEP's oil and gas staff complement has been decreased from 226 employees to 190 employees. Well permit review staff have been reduced by 43% in the Southwest District Office, and by 15% in the Northwest District Office. These reductions have unquestionably impacted the timeliness of permit review, and the department's ability to oversee its responsibilities.
> (http://files.dep.state.pa.us/LicensingPermitsCertification/PermitDecisionGuaranteePortalFiles/Permitting_Reform_01262018.pdf)

PADEP has asked the Governor and General Assembly to increase permit application fees to help increase regulatory staff in its Oil and Gas Program.

Leakage from new well casings is common; over time the failure of cement casing can affect large numbers of frack well bores, allowing the uncontrolled escape of methane and other pollutants into aquifers and the surface environment (Ingraffea *et al*. 2014). In consequence, about 10,000 complaints of stream and well pollution in lands where gas and oil drilling and fracking are underway have been filed with State regulators in Pennsylvania over the past decade in response to encounters with the consequences of pollution from some 11,000 new oil and gas wells (all drilled outside the Basin). But documenting the sources responsible for specific episodes of water contamination often proves difficult. Meanwhile, opportunities for public participation in decisionmaking about fracking are limited, and shortages of information have generated widespread concern among residents of oil and gas fields where HVHF is utilized.

Drawing upon the growing scientific literature, DRBC staff summarized the dangers associated with shale gas production using fracking in their notice of proposed rulemaking (http://www.nj.gov/drbc/meetings/proposed/notice_hydraulic-fracturing.html). There is no need to repeat that well organized information here. Schmid & Company staff concur that the proposed permanent ban on fracking in the Basin is warranted for the reasons set forth by DRBC in that document in order to protect the waters of the Basin, human health, and the environment. Keeping unconventional oil and gas operations out of the Basin will eliminate a potentially major consumer and polluter of water. It also will bar from the Basin a poorly understood source of human health problems associated with unconventional well pads and the vehicular traffic and diesel generators associated with them as HVHF industrial uses spread into residential landscapes (Currie, Greenstone & Meckel 2017).

Based on drilling elsewhere in Pennsylvania, many shale gas HVHF wells may be sited in upstream headwaters distant from major rivers. Prohibition of fracking is an efficient means of protecting water quality directly in the 40% of Basin land underlain by Marcellus and Utica Shales. In most of those shale-gas lands (which overall are about 85% forested; http://www.nj.gov/drbc/library/documents/bush_CDRWforum102214.pdf), the streams have been designated Special Protection Waters by DRBC. Streams in the Schuylkill River subbasin and other waters discharging into the tidal Delaware River below Trenton have not been designated as Special Protection Waters by DRBC.

Six of the seven concerns listed above obviously are benefited by a permanent ban on fracking and require no discussion here. The seventh DRBC concern---economic development---also is virtually certain to be benefited. Fracking poses very real risks at present to human health and to the environment in the Basin in consequence of 1) primitive available technology for gas extraction and waste treatment, 2) the minimal inventory of potentially affected resources currently required by DRBC and other agencies for permitting, 3) the scarcity of qualified personnel reviewing permits and inspecting operations on the ground and low probability of increased regulatory budgets, 4) the uncertain and fluctuating economic demand for natural gas that has long characterized the boom-and-bust oil and gas industry that has produced focus on quick production and profit with slight concern for long-term consequences, and 5) the ever-growing certainty that most known reserves of fossil fuels worldwide must be kept permanently unburned and below ground to forestall massive climate disruption (McGlade & Ekins 2015). These concerns exist over and above the localized resource damages from fracking that threaten vital water resources, recreation, tourism, and other sustainable economic activities within the Basin. The sacrifice of long-term economic and environmental values within the Basin’s tiny proportion of the shale gas resource land on behalf of short-term benefits from HVHF gas flowing primarily to large energy corporations would not be prudent. Were the shale gas ever needed by future generations of people, it could be extracted by them, potentially with far less damaging consequences as a result of technological advances unknown at present.

Hence this report concentrates on the export of fresh water associated with HVHF gas production from and import of produced frackwater into the Basin, which the DRBC proposes to regulate. Based on experience elsewhere in Pennsylvania during the past decade, the drilling industry would be expected to seek approval for water withdrawals from and discharges of treated wastewater to streams situated high in the watershed along headwaters relatively close to drilling pads. The use of wells drilled specifically for extraction of groundwater for shale fracking or for disposal of wastewater by injection has not been common in Pennsylvania. Injection wells for frackwater disposal elsewhere have led to earthquakes. We have concerns that DRBC authorization of import and export of waters used in unconventional oil and gas production may prove unwise as well as inconsistent, and we recommend that import and export of frackwaters---like fracking wells themselves---also should be banned permanently in the Basin. These activities pose many of the same likely impacts on water resources as drilling and fracking operations, with even less opportunity for economic benefits to Basin residents.

The Regulation of Fracking

The DRBC currently relies, and proposes in the future to rely, primarily upon State and federal regulators who implement the programs of other agencies to protect the public and the environment from the impacts of exporting freshwater to and importing produced wastewater from HVHF gas wells constructed outside the Basin. DRBC seeks to minimize regulatory duplication through coordination of its permit review and approvals with other agencies and via administrative agreements with the States. Historically, DRBC has focused chiefly on water quantity management and secondarily on water quality preservation. The information uniquely solicited by its current permit application forms primarily concerns water quantity.

At present DRBC has established no limit on the total volume of water that can be exported from or of wastewater that can be imported into the Basin. Instead, its permits (granted primarily to public utilities) to export an average of more than 100,000 gallons per day (based on a 30-day average) of fresh water from the Basin for any purposes other than oil and gas production ordinarily---after permit review---are deemed to have no substantial effect on the Basin's resources. Smaller withdrawals are not required to undergo DRBC review or obtain permits at all, unless specifically so notified. A lower minimum threshold for groundwater withdrawal review is set at 10,000 gallons per day in the Southeastern Pennsylvania Groundwater Protected Area consisting of parts of five counties, where shortages have been most problematic. DRBC seeks to impose restrictions on water withdrawal during periods of drought, and it assigns lower priority to industrial than to domestic water uses.

The withdrawal of any quantity of surface water or groundwater within the Basin for the purposes of HVHF, however, is proposed to require a full permit review. DRBC hopes somehow to "discourage" approval of such permits. The quantities of water extracted from the Basin at various locations for HVHF use are likely to be much more variable over time than the extraction of water by public utilities for potable water supplies. There are no currently approved DRBC permits for this purpose.

Because the capacity of the Basin's waters to accept treated wastewater also is considered limited, DRBC reviews permit applications to import more than 50,000 gallons per day (30-day average) of most wastewaters into (or to export such wastewaters out of) the Basin. The lower import permit threshold for typical wastewater discharges reaching Special Protection Waters is 10,000 gallons per day. The importation or treatment of produced frackwater in any quantity into the Basin, however, is proposed not to be allowed except after DRBC permit approval. Fracking wastes are considered to be different from other wastewaters currently discharged into the Basin. There are no currently approved DRBC permits for this purpose.

The proposed regulations would continue to allow the future export or import of water associated with HVHF if and when permits are requested by the industry. Future discharge of HVHF wastes anywhere within the Basin would be allowed only after treatment in a centralized waste treatment (CWT) facility. DRBC apparently would require a permit for all such transfers regardless of volume, as well as requiring approval of each CWT itself. Centralized waste treatment is an industrial category subject to specific US Environmental Protection Agency regulations for treatment technology. DRBC expects that the continuing imposition of its permit review would “discourage” proposals to transfer out-of-basin oil and gas wastewaters to CWTs discharging into Special Protection Waters, consistent with longstanding DRBC policy regarding direct discharges (Water Quality Regulations 3.10.3.A.2.c.[1]). Most CWTs for frackwaters would be expected to discharge directly into streams in accordance with a National Pollutant Discharge Elimination System permit, because USEPA has now banned the discharge of treated frackwaters into publicly owned treatment works. Each applicant would have to demonstrate an absence of out-of-basin alternatives (including the no-project alternative), as well as detail the impacts of each alternative on and benefits to the Basin. Applications for all frackwater import also would have to include a treatability analysis by a licensed engineer showing that the discharge by the intended CWT will meet all applicable standards plus achieve no exceedance of background concentrations in ordinary receiving waters and no measureable change (except toward natural conditions) in Special Protection Waters, as calculated by DRBC.

It is not clear why DRBC is proposing to allow, yet discourage, the export of fresh water to and import of frackwater generated by out-of-basin HVHF activities, while banning those activities within the Basin itself. The term “discourage” is not defined in the DRBC regulations, which are silent as to how the term might be applied. Perhaps DRBC deems the proposed fees at 18 CFR 401.43 constitute sufficient discouragement. No specific criteria that must be met to overcome discouragement are set forth in the DRBC proposal.

DRBC regulations already require submission of State approvals of proposed large freshwater withdrawal and wastewater discharge activities as part of its permit applications. Thus it is appropriate to examine the information required in DRBC applications. Traditionally DRBC has regulated water export from the Basin in large quantities on a relatively permanent basis by municipal users. The hydraulic fracturing of a well requires millions of gallons of water during a period of about one week, followed by flowback of hundreds of thousands of gallons of polluted water over a relatively short period. After that occurs a much reduced flowback of produced water throughout the life of the well. After a period of years the entire fracking process may be repeated to stimulate the ever dwindling flow of shale gas. The quantities of water used can be significant in small streams near the headwaters at the edges of the Basin and locally wherever groundwater resources are scarce. Over time a given withdrawal point on a stream or other body of surface water can be used to supply many wells on nearby pads, and a CWT capable of treating frackwater can generate variable flows of wastewater discharged into a stream. Thus the impacts from withdrawal of water and discharge of treated waste can vary depending on site conditions. Depending on the timing of gas well development, simultaneous fracking activities can occur in localized areas of abundant production ("sweet spots"). This could concentrate water import and export into relatively short, intense periods of time and into localized clusters of water resources.

There is little information concerning the potential impacts of such withdrawal and/or discharge in specific Basin watersheds, and permit applications at present do not require documentation of baseline conditions against which any resulting changes could be compared. Permit conditions imposed by DRBC do not require biological monitoring of impacts from approved facilities. DRBC apparently would have to close this regulatory gap, but has not explained how it plans to do so.

Withdrawal of Fresh Water for Fracking

DRBC has not explained how it intends to implement the requirements of its *Water Code* and *Water Quality Regulations* when authorizing stream water withdrawal for HVHF uses. In particular, it does not indicate how it will assure compliance with its adopted biocriteria. Those biocriteria appear not to be addressed by other agencies. DRBC has offered no detailed regulations or technical guidance specifying how such assessments will be made and reported in order to fill the current regulatory gap.[2]

Fresh water for transport to HVHF activities outside the Basin could be purchased from municipal suppliers using surface or groundwater sources, if they have excess approved capacity, apparently without specific DRBC approval. It is not clear whether DRBC notification would be required for such HVHF-related purchases, and the ultimately

---

[2] Other segments of the fossil fuel industry already are required to inventory baseline conditions and monitor impacts on macroinvertebrates and other existing conditions in streams at risk of biological degradation by loss of flow or discharge of pollutants. PADEP, for example, has adopted requirements for inventory and assessment of macroinvertebrates as part of its comprehensive stream monitoring in permit applications for coal mining activities [*see* 25 *Pennsylvania Code* §89.35; PADEP Bituminous Underground Mining Permit Application Module 8, Form 5600-PM-BMP0324, last revised July 2013; and PADEP Technical Guidance Document 563-2000-655].

adopted language should make this clear to all parties. Fresh water also could be withdrawn from specifically drilled wells following DRBC permit approval. To date water for fracking in Pennsylvania has been obtained primarily from surface sources rather than from groundwater.

Import of Produced Wastewater

USEPA prohibits the unregulated discharge of pollutants to surface waters of the United States from the onshore oil and gas industry. The discharge of wastewaters that contain pollutants is authorized by permits issued in accordance with the misleadingly named National Pollutant Discharge *Elimination* System administered primarily by the States. DRBC coordinates its discharge approvals with NPDES requirements and permits. Now DRBC proposes to authorize, yet also somehow to "discourage," future discharges of treated HVHF wastewater generated by oil and gas activities operating outside the Basin into waters within the Basin by requiring them to use approved CWTs.

DRBC and other agencies have established maximum concentrations of several specific pollutants allowable in wastewaters discharged from CWTs and into Special Protection Waters and other surface waters. DRBC regulations state that the most stringent applicable effluent limitations apply. Despite many years of study, USEPA has not established federal standards for treatment of fracking wastewater at CWTs. USEPA has prohibited the processing of frackwater at publicly owned wastewater treatment works (POTWs). Apparently DRBC has no plans to do so. Not all specific chemicals or combinations of chemicals that appear in frackwater have been assigned effluent limitations by any agency.

DRBC proposed regulations do not require baseline biological inventory or stream monitoring in receiving waters during wastewater discharge operations, as appears especially warranted at minimum in the Basin's Special Protection watersheds if future discharges of treated water were to be permitted for frackwater wastes generated outside the Basin. Such baseline inventory and biological monitoring by permittees is warranted to insure that the DRBC biocriteria for Special Protection Waters are being maintained. Such data should be collected and reported by applicants, used to assess habitat features and potential impacts of changing the flow regime on the species and habitats present, submitted electronically, and made available for timely review by the affected public during the review period for permit applications. The monitoring data also should be reviewed and publicly reported annually by DRBC staff to substantiate industry compliance with DRBC requirements for water resource protection. As noted above, biological monitoring already is required for potentially polluting discharges in other segments of the fossil fuel industry.

It is not clear whether each driller proposing to dispose any truckload of frackwater, wherever generated, anywhere within the Basin must apply to DRBC for a permit, although each CWT seeking to accept and treat frackwater apparently would have to do so. If every individual truckload of HVHF waste entering the Basin is going to require a separate permit from DRBC, a great deal of paperwork may be generated, and DRBC must specify precisely what information will be needed in such applications.

Landfill Leachate

Given the DRBC's focus on water resource protection, it is not unreasonable that it clarify its regulations at proposed 18 *CFR* 401.35(b)(14) to focus its concerns with landfill leachate, as opposed to other aspects of landfill regulation. Compact States have their own regulations governing the siting and operation of landfills.

Wetland Regulation

Wetlands are among the most threatened ecosystems on our planet. They are degraded and converted to human uses more rapidly than any other ecosystem, and the status of freshwater species is deteriorating faster than for other species. Since wetlands are essentially characterized by hydrologic conditions, changes in water volumes and timing of flows are major threats, as are discharges of various pollutants (Verones *et al*. 2013, Zedler 2005). Withdrawals of surface waters or groundwaters, and discharges of wastewaters have the potential for negatively impacting wetlands throughout the Basin. Given its focus on water quantity and quality, DRBC probably could oversee proposed changes in hydrology to wetlands within the Basin, especially including wetland drainage, more effectively than other agencies that focus on the placement of structures and fill material into wetlands and other regulated surface waters.

DRBC typically restricts its review of projects affecting wetlands to those projects affecting more than 25 acres of wetlands. It deems projects affecting less than 25 acres of wetlands normally as not having a substantial effect on the water resources of the Basin [18 *CFR* 401.35(a)(15)]. It is not clear that a 25-acre minimum threshold for wetland review is appropriate, especially if DRBC considers it essential to review water withdrawals and discharges of any size within the Basin when those activities are related to oil and gas development. Other agencies may not be able to review the impacts of proposed water withdrawals from and discharges into wetlands as thoroughly as DRBC staff.

The proposed change at 18 *CFR* 401.35(a)(15) would make clear that DRBC will review proposed impacts on wetlands involving less than 25 acres, but only when no State or federal agency already has done so. This could be an opportunity to partially fill a regulatory gap, but it is not clear how such a provision would be implemented. There are no detailed maps of regulated wetlands in the Basin. Existing National Wetland Inventory maps show the general location of wetlands recognizable from aerial photographs, but omit many forested wetlands, which are characteristic in the Special Protection watersheds of the Basin, and which offer special habitat values over and above other kinds of wetlands in this biome (Schmid & Co., Inc. 2014). DRBC has no capability of identifying small wetlands subject to impact that are not known already to other agencies. Similarly, published maps available from the United States Geological Survey and from the online National Hydrography database omit many headwater streams. Apparently DRBC expects to rely upon the affected public to identify small wetlands and streams at risk from its water-related permits that applicants and other agencies have overlooked. How it might condition its permits to protect such resources is not clear.

DRBC should issue detailed regulations and/or technical guidance for implementing its intended wetland review requirement. DRBC should require that applicants prepare detailed onsite field surveys and standard written documentation of the nature and extent of wetlands and other surface water conditions on any property to be disturbed by any proposed construction within the Basin associated with the regulated withdrawal of water or disposal of wastewater, and review all such information that has been compiled already for, and approved by, another State or federal agency.

Authorship

This report was prepared by James A. Schmid with the assistance of Stephen P. Kunz. Dr. Schmid is a biogeographer and plant ecologist with 45 years of applied environmental consulting experience in the mid Atlantic States. Mr. Kunz is a Senior Ecologist at Schmid & Company with 40 years experience in environmental consulting. Both Dr. Schmid and Mr. Kunz are certified as Senior Ecologists by the Ecological Society of America, as Professional Wetland Scientists by the Society of Wetland Scientists, and as Wetland Delineators by the Army Corps of Engineers.

References Consulted

Adams, M. B. 2011. Land application of hydrofracturing fluids damages a deciduous forest stand in West Virginia. *Journal of Environmental Quality* 40(4):1340–1344.

Brantley, S. L., D.A. Yoxtheimer,, S. Arjmand,, P. Grieve, R. Vidic, J. Pollak, G.T. Llewellyn, J. Abad, and C. Simon. 2014. Water resource impacts during unconventional shale gas development: The Pennsylvania experience. *International Journal of Coal Geology* 126:140–156.

Currie, Janet, M. Greenstone, and K. Meckel. 2017. Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Science Advances* 3(12).

Entrekin, S., M. Evans-White, B. Johnson, and E. Hagenbuch. 2011. Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment* 9(9):503–511.

He, Can, T. Zhang, X. Zheng, Y. Li, and R.D. Vidic. 2014. Management of Marcellus shale produced water in Pennsylvania: a review of current strategies and perspectives. Energy Technology 2(12):968-976.

Hladik, M.L., M.J. Focazio, and M. Engle. 2014. Discharges of produced waters from oil and gas extraction via wastewater treatment plants are sources of disinfection by-products to receiving streams. *Science of the Total Environment* 466–467:1085–1093.

Ingraffea, Anthony R., M.T. Wells, R.L. Santoro, and S.B.C. Shonkoff. 2014. Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012. *Proceedings of the National Academy of Sciences* 111(30):10955-10960.

Jackson, R. B., A. Vengosh, J.W. Carey, R.J. Davies, T.H. Darrah, F. O'Sullivan, and G. Pétron. 2014. The environmental costs and benefits of fracking. *Annual Review of Environment and Resources* 39:237– 362.

Llewellyn, G.T. 2014. Evidence and mechanisms for Appalachian Basin brine migration into shallow aquifers in NE Pennsylvania, USA. *Hydrogeology Journal 22*(5):1055–1066.

McGlade, Christophe, and P. Ekins. 2015. The geographical distribution of fossil fuels unused when limiting global warming to 2° C. *Nature* 517:187-190.

Maloney, Kelly O., J.A. Young, S.P. Faulkner, A. Hailegiorgis, E.T. Slonecker, and L.E. Milheim. 2018. A detailed risk assessment of shale gas development on headwater streams in the Pennsylvania portion of the Upper Susquehanna River Basin, U.S.A. *Science of the Total Environment* 610-611:154-166.

Maloney, Kelly O., S. Baruch-Mordo, L.A. Patterson, J-P. Nicot, S.A. Entrekin, J.E. Fargione, J.M. Kiesecker, K.E. Konschnik, J.N. Ryan, A.M. Trainor, J.E. Saiers, and H.J. Wiseman. 2017. Unconventional oil and gas spills: Materials, volumes, and risks to surface waters in four states of the U.S. *Science of the Total Environment* 581-582:369-377.

Maloney, Kelly O., and D.A. Yoxtheimer. 2012. Production and disposal of waste materials from gas and oil extraction from the Marcellus shale play in Pennsylvania. *Environmental Practice* 14(4):278-287.

Patnode, Kathleen A., E. Hittle, R.M. Anderson, L. Zimmerman, and J.W. Fulton. 2015*.* Effects of high salinity wastewater discharges on unionid mussels in the Allegheny River, Pennsylvania. *Journal of Fish and Wildlife Management* 6(1):55-70.

Patterson, Lauren A., K.E. Konschnick, H. Wiseman, J. Fargione, K.O. Maloney, J. Kiesecker, J-P. Nicot, S. Baruch-Mordo, S. Entrekin, A. Trainor, and J.E. Saiers. 2017. Unconventional oil and gas spills: Risks, mitigation priorities, and state reporting requirements. *Environmental Science and Technology* 5(15):2563-2573.

Rahm, B. G., J.T. Bates, L.R. Bertoia, A.E. Galford, D.A.Yoxtheimer, and S.J. Riha. 2013. Wastewater management and Marcellus Shale gas development: Trends, drivers, and planning implications. *Journal of Environmental Management* 120:105–113.

Rhodes, A.L., and N.J. Horton. 2015. Establishing baseline water quality for household wells within the Marcellus Shale gas region, Susquehanna County, Pennsylvania, USA. *Applied Geochemistry* 60:14–28.

Schmid & Company, Inc. 2014. The effects of converting forest or scrub wetlands into herbaceous wetlands in Pennsylvania. Prepared for the Delaware Riverkeeper Network. Media PA. 48 p.

Skalak, K. J., M.A. Engle, E.L. Rowan, G.D. Jolly, K.M. Conko, A.J. Benthem, *et al*. 2014. Surface disposal of produced waters in western and southwestern Pennsylvania: Potential for accumulation of alkali-earth elements in sediments. *International Journal of Coal Geology* 126:162–170.

Verones, Francesca, D. Saner, S. Pfister, D. Baisero, C. Rondinini, and S. Hellweg. 2013. Effects of consumptive water use on biodiversity in wetlands of international importance. *Environmental Science & Technology*47:12248−12257.

Vidic, R.D., S. L. Brantley, J.M. Vandenbossche, D. Yoxtheimer, and J.D. Abad. 2013. Impact of shale gas development on regional water quality. *Science* 340(6134).

Zedler, J. B., and S. Kercher. 2005. Wetland resources: Status, trends, ecosystem services, and restorability. *Annual Review of Environmental Resources* 30:39−74.

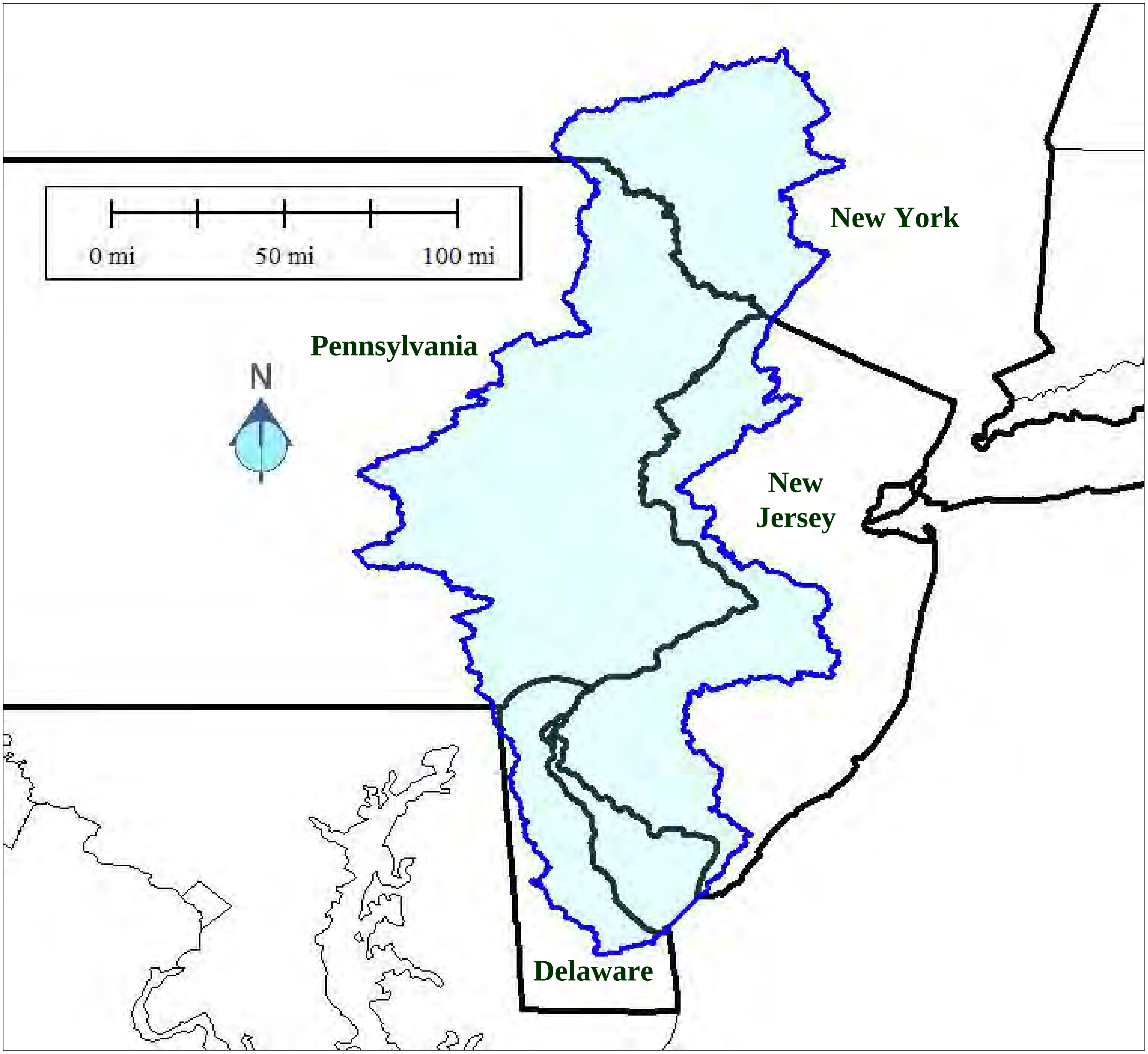


FIGURE 1. Location of the Delaware River Basin (blue) in Pennsylvania, New York, New Jersey, and Delaware.

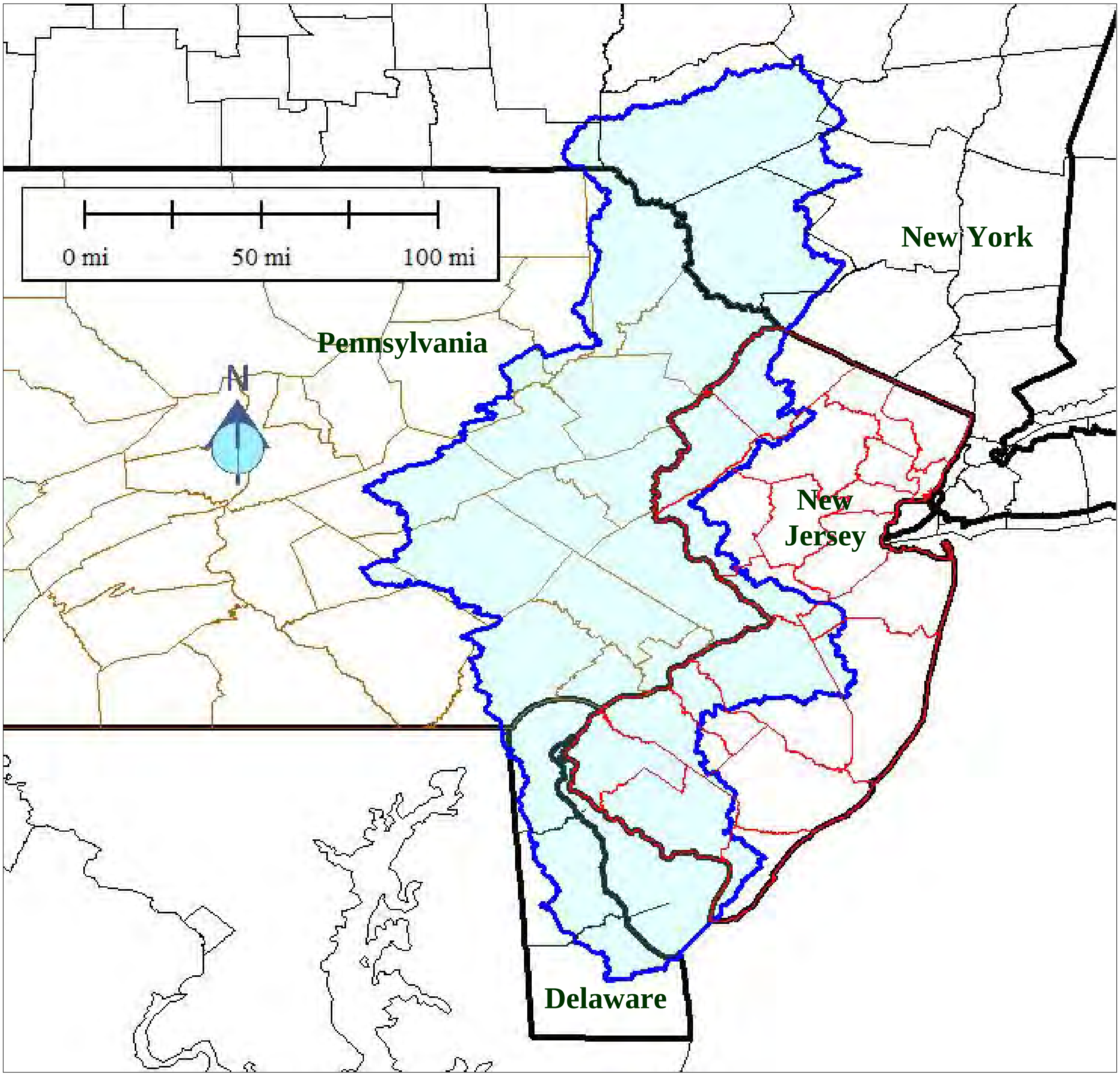


FIGURE 2. Location of the Delaware River Basin (blue) in Pennsylvania, New York, New Jersey, and Delaware, with counties outlined.

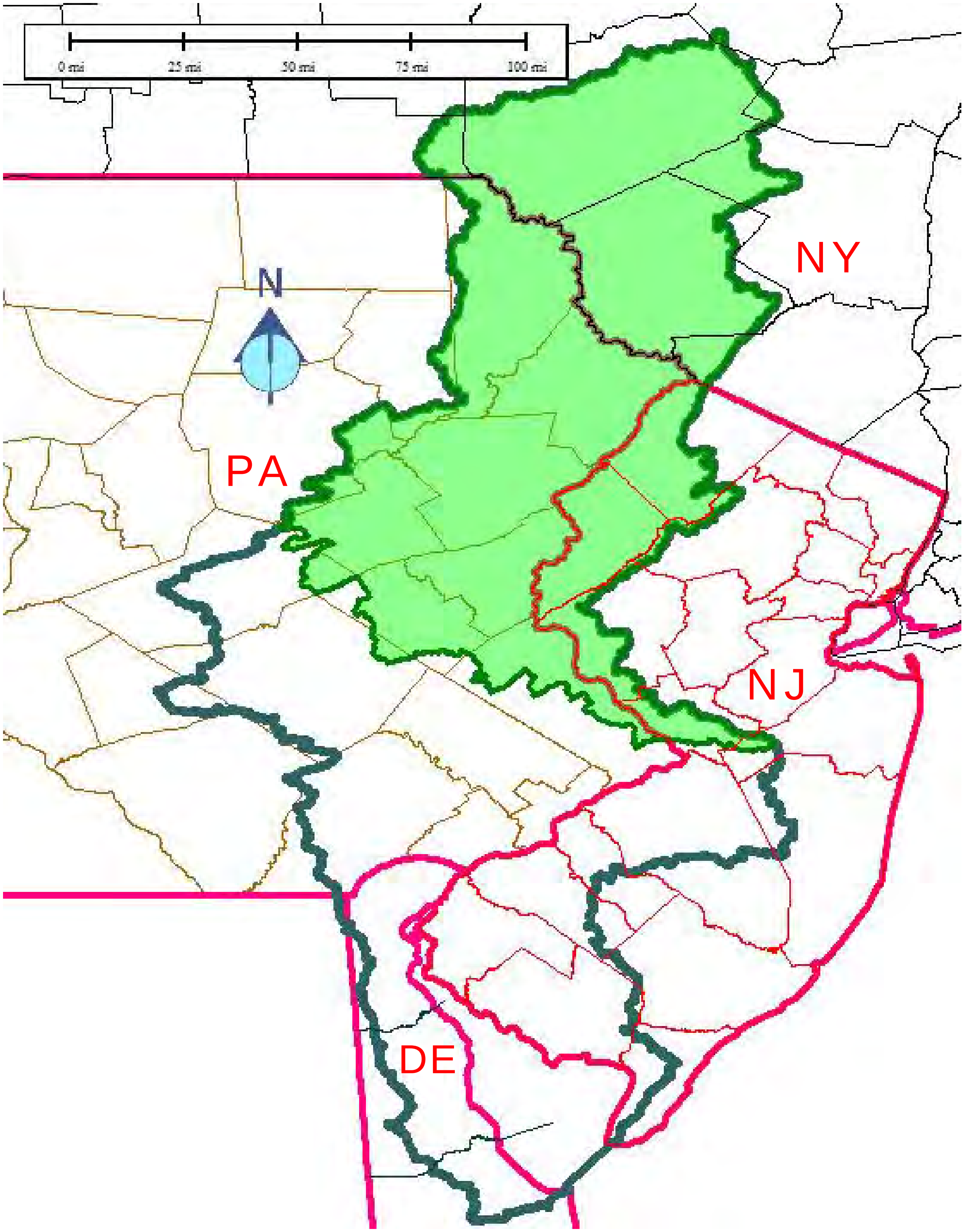


FIGURE 3. Identification of the Special Protection Waters area (green) within the jurisdiction of the DRBC (heavy outline) and member states (red). Counties also are shown. Approximately 50% of the DRBC Special Protection Waters are in PA, 35% are in NY, and 15% are in NJ.

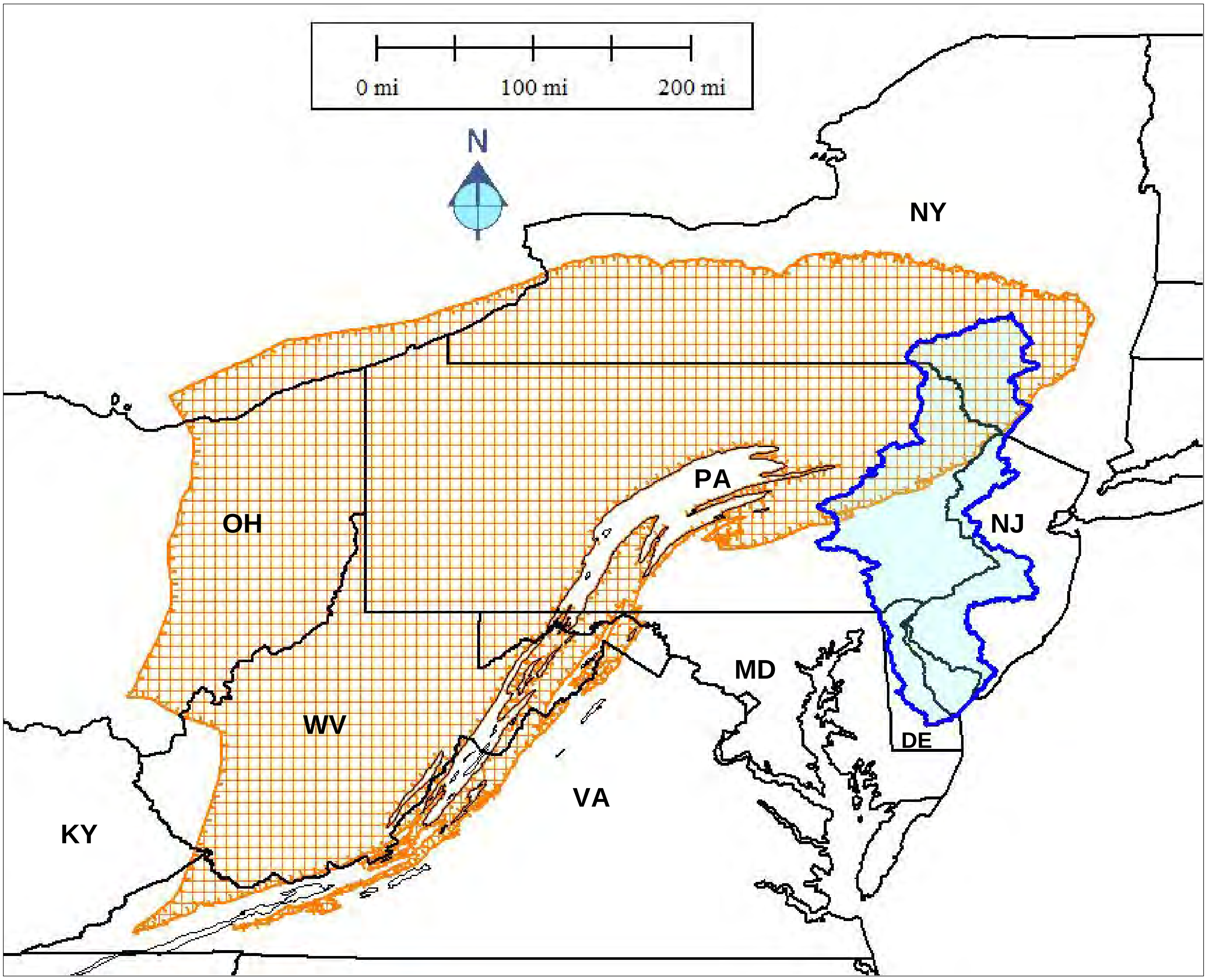


FIGURE 4. Location of area within the northeastern United States underlain by Marcellus Shale reserves (orange crosshatch). Delaware River Basin is in blue. Only 5% of the Marcellus Shale is within the Delaware River Basin, and it is found only within Pennsylvania and New York.

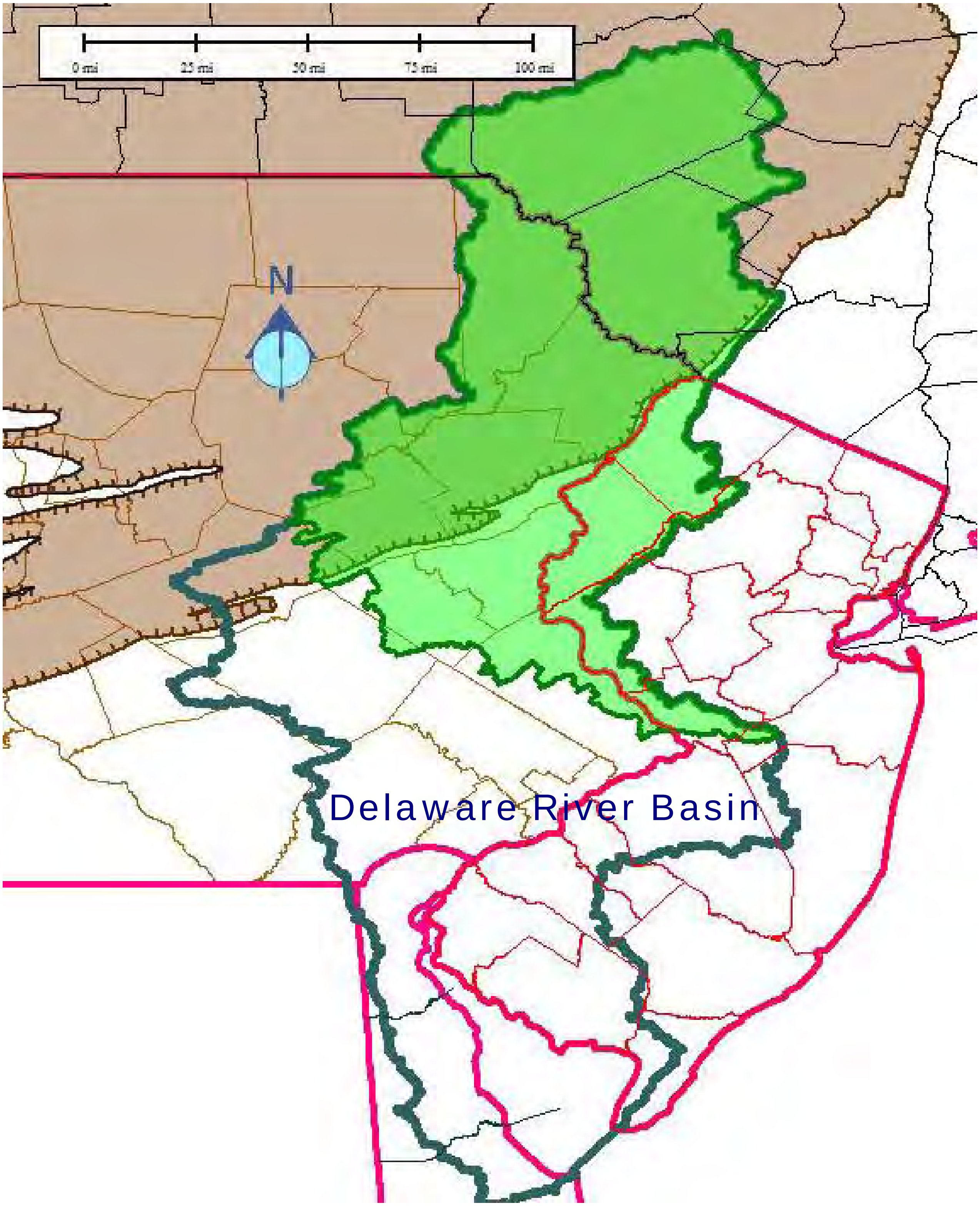


FIGURE 5. Location of Marcellus Shale reserves (brown) in relation to the Special Protection Waters section (green) of the Delaware River Basin (heavy outline). State boundaries are in red. Counties also are shown.

Ecological review of the DRBC Draft 18 CFR Parts 401 and 440

Proposed Amendments to the Administrative Manual and Special Regulations

Regarding Natural Gas Development Activities.

February 2018

Report

prepared for

Delaware Riverkeeper Network

Prepared by

Piotr Parasiewicz, PhD, A.Prof.

616 Corporate Way, Suite 2-3932 | Valley Cottage, NY 10989 | www.rushingrivers.com| piotr@rushingrivers.com | 617 500 4884

EXECUTIVE SUMMARY

This testimony addresses the question whether the proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas are adequate to protect the ecological resources of the Delaware River Basin. The proposed 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations, with its additions and revisions, rule making notice were reviewed, as well as the efforts to establish an Ecological Flow Regime for the Upper Delaware River. The regulations are analyzed through the prism of the ecological data gathered by the scientists working on the Delaware River and is supported by a review of publications and scientific reports related to the Delaware River.

A thorough review of existing information made it clear that complete prohibition of shale gas extraction is an appropriate decision for protection of public health and resources in the Delaware River Basin. This prohibition, however should also include water exportation from and wastewater imports to the Watershed. Offering permitting options will encourage development of extraction wells in near proximity of the Delaware Watershed imposing the public and wildlife to associated risks. Particularly the substantial uncertainty with long term effects of the pollutants in produced water and our ability of stopping them from entering into the waters of the area calls for very strict regulation without permitting options.

I concluded that the regulations, which even contemplate permitting options for water exportation and waste water imports are contrary to current efforts of the DRBC to protect and maintain healthy aquatic populations, which is declared as the goal in the Water Resources Plan. I recommend that the prohibition of Natural Gas Development within the Delaware River Basin will be full and includes water exportation and wastewater importation for these purposes.

I. STATEMENT OF QUALIFICATIONS

1. **Education.** I received a Ph.D., M.S. and G.E. in natural resources management and water engineering with a focus on fisheries ecology from the University of Agricultural Sciences in Austria. I am also professor in Inland Fisheries awarded from the S. Sakowicz Inland Fisheries Institute in Poland. My Curriculum Vitae is provided as **Exhibit 1**.
2. **Experience.**
    a. I am an associate professor at S. Sakowicz Inland Fisheries Institute in Poland, August-Wilhelm Scheer Visiting Professor 2018 at the Technical University of Munich in Germany, Honorary Fellow of TUM Institute for Advanced Study and adjunct professor at the University of Nebraska Lincoln.
    b. I am the founder and director of Rushing Rivers Institute, a non-profit organization promoting river science in river management.
    c. I have been a Research Associate at the Department of Natural Resources of Cornell University, a Research Associate Professor at the Department of Natural Resources Conservation at the University of Massachusetts and held the position of Research Associate Adjunct Professor and Director of the Northeast Instream Habitat Program at Mt. Holyoke College in South Hadley, Massachusetts.
    d. I am also a founding member of the International Aquatic Modeling Group, and a member of the American Fisheries Society, the River Management Society, the International Society for River Science, the International Association for Hydraulic Research.
    e. I developed the MesoHABSIM model and the associate SimStream software, a

computer simulation system for fish and mussel habitat restoration planning that has been applied around the US and abroad and is currently used for the development of Protected Instream Flow Standards in the State of New Hampshire, Poland and Italy.

f. My primary research area is in the assessment and simulation of physical habitats for fish and invertebrate communities as a basis for ecosystem restoration. My recent projects focus on river habitat simulation, instream flows and comprehensive river restoration planning.

g. I have 32 years of extensive experience in the planning and implementation of river restoration projects, the design of nature-like bypass channels to support fish passage and the restoration of migratory species, as well as the assessment of ecological integrity.

h. I have assisted in the drafting of laws and policies to protect instream flow in the states of MA, NH, CT and Poland. These projects are designed to determine water allocation methods with the goal of balancing human needs with ecological needs.

i. I am very familiar with the Upper Delaware River, the adjacent area and issues involved in flow management. I was a project leader on the study of Dwarf Wedgemussel Habitat in the Upper Delaware River and a member of the Subcommittee for Ecological Flows for Delaware River Basin Commission. The results of the study are published in three high impact research journals.

II OPINIONS

1. My report is organized as follows. In the Background section, I describe the circumstances of the rule and my professional perspective on the overall impact and proposed permitting conditions. In following sections, I address the technical issues and concerns associated with the proposed rule. The conclusions and recommendation sections provide a brief synopsis and the conclusions of my review.

Background

2. The dramatic impact of human-induced alterations on freshwater flora and fauna is widely reported (Gleick et al., 2001; UNEP, 1999). Running water ecosystems belong to the most severely human-impacted habitats on Earth (Nilsson et al., 2005; Malmqvist and Rundle, 2002). Of more than 3,500 species currently threatened with extinction worldwide, one-quarter are fish and amphibians.
3. In freshwaters, the projected decline in species diversity is about five times greater than in terrestrial ecosystems (Pimm et al., 1995). This rate is similar to that of great prehistoric extinctions (Malmqvist and Rundle, 2002).
4. It has been suggested that some 30-35% of all freshwater fish species are already extinct or in serious decline worldwide (Stiassny, 1999). Ninety-three percent of these reductions occurred during the last 50 years, indicating extinction of freshwater fishes is a serious and accelerating global trend (Harrison and Stiassny, 1999).
5. The freshwater mussel is one of the most imperiled animal groups in North America with only 25% of the existing species having stable populations (Williams et al., 1995). Freshwater mussels fulfill many crucial ecosystem services such as the filtering of large

amounts of water, which removes pollutants from the water. Hence, healthy assemblages of mussels are necessary to maintain high water quality standards.

6. Historical and ongoing urbanization of our landscape intensifies floods and droughts, causing damage to human property and stressing the fauna. Excessive water withdrawals due to human and industrial demands dry up rivers with increasing frequency.
7. The process of urbanization alters seasonal hydrographs by increasing peak flows and decreasing base flows (e.g., Bedient and Huber, 1988; Dunne & Black, 1970; Parasiewicz and Goettel, 2003; Petersen, 2001). In the Northeastern United States, this hydrological pattern appears to be a regional phenomenon and a lasting legacy of historic deforestation. Even in areas such as the Catskill Mountains that superficially appear to have recovered from the historical impacts of earlier timber harvests, similar effects can still be observed (Parasiewicz et al., 2010).
8. The change in our global climate further contributes to this impact by causing higher summer air temperatures, a longer summer season, and lower minimum river flows together with more frequent and severe flooding (Faloon and Betts, 2006).
9. The water in these reduced flows tends to warm up more quickly in rivers that have been widened by previous floods and historical logging operations. Shallow ponds, created by thousands of small dams, serve as natural solar collectors. Additionally, less cold water is entering the rivers from base flow because of increased ground water withdrawals. We are frequently now measuring summer water temperatures in excess of 80°F in long stretches of "coldwater" streams (e.g. Ballestero et al., 2007, Parasiewicz et al., 2007).
10. Consequently, scientists anticipate a loss of coldwater fauna from rivers and streams of the Northeastern United States and recommend that proactive management preventing

extended droughts and low flow levels by avoiding excessive water withdrawals must be a management priority.

11. Silk et al. (2000) eloquently suggests that “The natural ecosystem of any river is the product of millions of years of adaptation and evolution, which have created a myriad of variables and subtleties more complex than we can imagine.” Due to this complexity and continuing conflicts of interest among competing water uses, a very precise planning and evaluation of potential development impacts is required.
12. Water allocation issues are not new, and many techniques have been developed in recent decades to address these problems (Stalnaker, 1995; Dunbar et al., 1998). Only recently we learned to recognize that not only is the quality and quantity of water released below a hydro-power or irrigation dam important, but also that modifications of hydrological patterns can have detrimental effects on aquatic life (Richter et al 1997).

Delaware River Watershed

13. The Catskill Mountains’ and Poconos watersheds are generally rural, topographically steep areas with shallow, permeable soils overlaying restrictive bedrock or fragipans. Heightened flow peaks cause severe erosion, leading to the down-cutting and over-widening of river corridors (Parasiewicz et al., 2010). The notable lack of woody debris structure documented in the Stony Clove Creek study in the Catskill Mountains (Parasiewicz et al., 2003) was partially a consequence of increased flow peaks removing log jams before they can stabilize, but also due to frequent “cleanups” of woody debris as a flood protection and beautification measure.
14. These changes, in combination with reduced stream flows and groundwater levels, increase summer water temperatures and can cause creation of anchor ice in the winter.

Anchor ice is an ice forming at the bottom of the river that can create considerable damage to the aquatic fauna by forcing fish movements and increasing their mortality. In addition, many river corridors, especially those in urbanized areas, have been physically modified (e.g., straightened, widened, dredged or impounded), altering the character of the corridor (e.g. from braided to straightened) and leading to further modifications in the hydrological regime (Hewlett and Hibbert, 1967).

15. The most apparent consequences of such changes in hydrological patterns are a reduction in fish densities and modification of the fish community structure from specialized riverine species towards more generalized species. This phenomenon has been documented in several recent studies in the Northeast Region (eg. Parasiewicz and Goettel, 2003; Armstrong et al., 2001).

16. The Delaware River is considered an exceptionally healthy river mostly because of the length of its free flowing section. Among outstanding characteristics, there is a considerable number of freshwater mussel species, including the federally endangered dwarf wedgemussel (*Alasmidonta heterodon*), as well as a large number of migratory fish species, notably American eel and American shad.

17. Proximity to northeastern metropolitan areas as well as low population density makes the Upper Delaware River also a very valuable recreational resource for boaters, hunters and others searching for outdoor adventure and tranquility. The region is famous for its fly-fishing, creating a valuable recreational industry. The watershed is home to the National Park Service Wild and Scenic River program and multiple natural conservation areas.

18. However, the legacy of deforestation and an industrial past is still visible in its over-widened, shallow river channels and flashy hydrology with rapidly changing flows from

very low to very high. The watershed is also under pressure for hydropower use and as a drinking water supply for New York City (Parasiewicz et al., 2010).

19. As mentioned in the Rulemaking notice Delaware River Basin provides water for over 15 milion people and much of it is drinking water.
20. The flows in the river are strongly influenced by releases from upstream reservoirs: Cannonsville on the West Branch, Pepacton on the East Branch, Wallenpaupack on the Lackawaxen River, Mongaup on the Mongaup River and Neversink on the Neversink River. A Supreme Court decree was needed to manage the downstream salt wedge in Philadelphia by mandating the minimum flow releases. Due to complex management objectives, the current flows in the river can be erratic and unpredictable.

21. Consequently, the habitat conditions are quite unstable and high water temperatures have caused fish die offs and potentially reduced mussel populations in the past. As documented by an investigation of dwarf wedgemussel habitat, the existing populations are limited to a few locations that maintain hydraulic stability. The sedentary organisms like freshwater mussels are particularly vulnerable to the habitat reduction due to the lack of water than can be caused by water withdrawals or rapid fluctuations.

Watershed Management

22. The Delaware River Basin Commission recognizes the unique value of the watershed and its vision statement commits to be "the leader in protecting, enhancing, and developing the water resources of the Delaware River for present and future generations." It includes "Protection and enhancement of ecological integrity" as a guiding principle of the Water Resources Plan. The DRBC adopted Special Protection Waters regulations to further protect a large portion of the watershed.

23. The same Rulemaking notice document cites the Delaware River Basin Laws stating the limitation of water availability in the Basin.

24. In consequence of a multiyear collaborative efforts the next Flexible Flow Management Plan including measures to protect federally endangered species such as the dwarf wedgemussel has been recently extended for another 5 years. It is a complex effort and intensive endeavor aiming towards managing numerous users and protecting the river ecology. During this time the DRBC and involved parties committed to continue investigations of the consequences of plan introduction searching for adaptive management options.

Impact of high volume hydraulic fracturing (HVHF)

25. The Rulemaking notice also very appropriately describes the impacts of HVHF, which are substantial and could threaten the public health and aquatic life of the watershed if permitted. With regard to the influence on the freshwater fauna there are three major issues:

    a. **Contamination**: Fracturing fluid pumped into the well entails water, chemicals, and proppants, which in the process also washes out contaminants from the target rock formations. Therefore, so called produced water consists of numerous pollutants such as

        i. salts, including chloride, bromide, sulfate, sodium, magnesium, and calcium;

        ii. Metals, including barium, manganese, iron, and strontium;

iii. Naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes (BTEX), and oil and grease;

iv. Radioactive materials, including radium; and

v. Hydraulic fracturing chemicals and their chemical transformation products.

Many of these substances are highly toxic and their treatment is costly.

b. **Flow reduction:** HVHF requires high volumes of water (between 4 to 11 million gallons per fracturing event on one well only). Such withdrawals could easily destabilize the carefully crafted web of Flexible Flow Management Plan and other protective regulations.

c. **Higher runoff by increasing floods and droughts due to development of well pads.** With construction of thousands of wells we can expect massive construction of well pads, road building, impoundments, and forest clearing that will cause increased frequency and intensity of flooding as well as the frequency and duration of droughts. This would sharply exacerbate the impacts of global climate change, which has very similar consequences. In effect, we can expect less and warmer water in summer, degradation of water quality and therefore shifts in fish and invertebrate community structure towards fewer, but more generalist (pond) species.

Proposed DRBC amendments to Natural Gas Development Regulations

26. In face of the above mentioned issues the proposed amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities rightly

prohibits the HVHF activities in the Delaware Basin for reasons of pollution control, protection of public health and preservation.

27. However, the Commission is willing to consider permitting *water exports* for utilization in hydraulic fracturing. Although the Commission requires also alternative analysis, in face of the ample evidence of water scarcity in the Delaware River Watershed this consideration seems to be inconsistent with declared policy of discouraging the exports.

28. Since HVHF requires substantial volumes of water there are two likely scenarios for which such exportation permit may be pursued by industry:

    a. Large volumes to run wells in close proximity of the Delaware River Basin watershed boundary. This scenario leads to asking DRBC to violate its own policy of discouraging the exportation and is threatening water availability in the basin. All above mentioned consequences affecting human and aquatic faunas health apply.

    b. Small volumes to supplement fracturing water taken elsewhere from river or aquifers in close proximity to watershed boundary. Similarly like in scenario a) such permit encourages construction of well pads in close proximity of the Delaware Watershed. With the ability of horizontal drilling with laterals up to 10000 ft, this may cause unintended impacts within the Delaware Watershed such as water contamination or even triggering small earthquakes.

29. In the proposed amendment the Commission is also willing to consider the approval of *importation of produced water* into the Delaware Watershed under condition of appropriate treatments.

30. Despite the requirement of alternatives analysis this proposition is also in contrast with

the declaration of protection of public health and aquatic life, because:

a. Many of the toxic substances occurring in the produced water of Marcellus Shale require special treatment with expensive technologies.
b. Safe concentration of some of these substances (total dissolved solids, barium, bromide, radium and strontium) are not yet regulated and treatability studies are still required even to characterize the pollutant loads in the produced water.
c. The long term bioaccumulation effects of these substances on biota is not well known. Water filtering organisms such as freshwater mussels may be particularly vulnerable to such toxic substances.
d. Similarly background concentrations that are required to be maintained according to the rule are yet to be determined.
e. Due to the fact that the produced water dissolves substances from target rock formation, it is conceivable that their concentration as well as their chemical composition may vary uncontrollably potentially exceeding the capacity of the treatment plant. Attempting to mitigate that would require toxic storage reservoirs with all associated and unacceptable risks of accidental breaching or leaching.
f. Transportation and handling of such substances is prone to accidental leaks, which are very difficult to control and account for.
g. It encourages the development of HVHF operations in the proximity of the Delaware Watershed with all the consequences described above.

Conclusions and Recommendations

31. The Upper Delaware River Watershed is a precious resource with a multitude of outstanding characteristics and users. The maintenance of the watershed's ecological

integrity requires careful and wise management. Such management is under development and measures that prevent degradation of aquatic fauna under climate change scenarios are not in place yet.

32. At this point adding more complexity and additional risks before such a program is in place is counterproductive, as obviously more time and resources are necessary to complete ongoing scientific efforts and take control over current issues in a way that will allow the protection and enhancement of ecological integrity.

33. Before contemplating any option associated with potential water withdrawals of any kind it would be necessary to conduct a comprehensive assessment of habitats and species in tributaries and main stem and to develop watershed models to forecast potential cumulative impacts. Such models need to inform the decision not only with regard to the possibility of water withdrawals, but also about necessary mitigation and compensation measures such as by-pass flows or channel improvements. Such documentation and models do not exist yet.

34. Therefore, I recommend that Natural Gas Development should be fully banned without encouraging HVHF activities, especially in the proximity of the Delaware River Watershed. This includes complete prohibition on water exports and wastewater imports for the purpose of natural gas mining as an unnecessary risk to the wellbeing and health of millions of citizens and the Delaware River Watershed's water resources and natural ecosystems, including the species that live there.

II. REFERENCES

45. In preparing this report, I completed the following tasks:

a. I reviewed the following documents:

i. DRBC 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations

ii. DRBC Water Resources Plan

iii. Water Resources Program 2010-2015

iv. Other pertinent information available on the website of DRBC

d. I have cited and referred to the following literature in this report:

A. Ballestero, T., D. Kretchmar, L. Carboneau, P. Parasiewicz, J. Legros, J. Rogers, T. Steger, J. Jacobs. 2006. Souhegan River Protected Instream Flow Report, NHDES- R-WD-06-50, Concord, NH. Report for New Hampshire Department of Environmental Services. http://www.des.state.nh.us/rivers/instream/souhegan/study.html

B. Bedient, P.B. and W.C. Huber 1988. Hydrology and Floodplain Analysis. Addison-Wesley Publishing Co. New York. 650 p.

C. Bovee, K.D., Waddle, T.J., Bartholow, J., and Burris, L., 2007. A decision support framework for water management in the upper Delaware River: U.S. Geological Survey Open-File Report 2007-1172, 122 p.

D. Brown, R. S, Hubert, W.A and Daly, S. E. 2011. A primer on winter, ice and fish: What fisheries biologist should know about winter ice processes and stream dwelling fish. Fisheries 1 (**36**): 8-26.

E. Campbell, C.A, Lellis, W.A and Cole, J.C. 2006 Qualitative Freshwater Mussel Survey of the Lower Neversink River. Administrative Report Prepared for the U.S. Fish and Wildlife Service, Region 5

F. Cole, J.C., White, B.S. and Apse, C. 2004. A quantitative assessment of freshwater mussels (Bivalvia:Unionidae) in the Neversink River prior to the Cuddebackville Dam removal. Report to The Nature Conservancy, Cuddebackville, New York. 16 pp.

G. Cole, J.C and White, B.S. 2006. An assessment of freshwater mussels in the Neversink River following removal of the dam at Cuddebackville, NY and a severe spring flood event. Report to The Nature Conservancy, Cuddebackville, NY. 12 pp.

H. Dunbar, M.J., Acreman, M.C., Gustard A., and Elliott C.R.N. 1998. Overseas Approaches to Setting River Flow Objectives. Phase I Report to the Environment Agency. – Environment Agency R&D Technical Report W6-161, Bristol.

I. Dunne, T., and Black, R.D. 1970. Partial area contributions to storm runoff in a small New England watershed. Water Resour. Res. 6: 1296-1311.

J. Faloon, P.D. and Betts, R. A. 2006. The impact of climate change on global river flow in HadGEMI simulations. Atmos. Sci. Let. 7:62–68(2006). www.interscience.wiley.com.

K. Gleick, P.H., A. Singh, and H. Shi. 2001. Emerging Threats to the World's

Freshwater Resources. A Report of the Pacific Institute for Studies in Development, Environment, and Security, Oakland, California.

L. Harrison, I.J., and M.L.J. Stiassny. 1999. The quiet crisis. A preliminary listing of the freshwater fishes of the world that are extinct or 'missing in action'. Pages 271-331 in R.D.E. MacPhee (ed.) Extinctions in Near Time. Kluwer Academic/Plenum Publishers, New York.

M. Malmqvist, B., and S. Rundle. 2002. Threats to the running water ecosystems of the world. Environmental Conservation 29: 134-153.

N. Nilsson, C., Reidy, C. A., Dynesius M. and Revenga C. 2005. Fragmentation and flow regulation of the world large river systems. Science 308: 405-408.

O. NYNHP Conservation Guide – Dwarf Wedgemussel. http://www.acris.nynhp.org/report.php?id=8375

P. Petersen, N. 2001. Philadelphia Inquirer, Thursday edition, September 13, 2001.

Q. Parasiewicz, P. (2001). Strategy for Sustainable Management of the Upper Delaware River Basin. Trout Unlimited. NY. 21pp

R. Parasiewicz, P. and Goettel, M.T. 2003. Ecohydrology Study of the Quinebaug River, Final Report. Instream Habitat Program and New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources, Cornell University, July.

S. Parasiewicz P., Ehmann, S. B. and Corp, P. 2003. Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM. Report for New York City Department of Environmental Protection and Green County Soil and Water Conservation District and New York State Water Resources Institute. pp 410.

T. Parasiewicz, P., J. Rogers, J. Legros and M. Wirth. 2007. Assessment and restoration of instream habitat of the Eightmile River in Connecticut – Developing MesoHABSIM model. The National Park Service, Wild and Scenic River Study for the Eightmile River and the Eightmile River Wild and Scenic Study Committee. pp 62. http://www.neihp.org/projects/eightmile/index.htm

U. Parasiewicz, O., Gillespie N., Sheppard D., Walter M.T. 2010. Strategy for Sustainable Management of the Upper Delaware River Basin. Environmental Research Journal. 5 (1). pp. 115-130

V. Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestergaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47: 769-784.

W. Pimm, S.L., G.J. Russell, J.L. Gittleman, and T.M. Brooks. 1995. The Future of Biodiversity. Science 269: 347-350.

X. Richter, B.D., Baumgartner, J.V., Wigington, R. and Braun, D.P. 1997. How much water does a river need? Freshwater Biology, 37 (1): 231-249.

Y. Stalnaker, C.1995. The Instream Flow Incremental Methodology: A primer for IFIM. – National Ecology Research Centre, Internal Publication. U.S Dept of the Interior, National Biological Service, Fort Collins, Colorado.

Z. Stiassny, M.L.J. 1999. The medium is the message: freshwater biodiversity in peril. Pages 53-71 in J. Cracraft and F.T. Grifo (eds.) The Living Planet in Crisis: Biodiversity Science and Policy. Columbia University Press, New

York.
AA. UNEP. 1999. Global Environment Outlook 2000.United Nations Environment Programme, Oxford University Press, New York.
BB. Williams, J.D, and Neves R.J. 1995. Freshwater Mussels: A Neglected and Declining Aquatic Resource. In LaRoe ET, Farris GS, Puckett CE, Doran PD, Mac MJ. Our Living Resources: a Report to the Nation on the Distribution, Abundance, and Health of US Plants, Animals, and Ecosystems. US Department of the Interior, National Biological Service, Washington DC, United States, 1995. 362 pp.
CC. Wiley, M.J., Hyndman, D.W., Pijanowski, B.C., Kendall, A.D., Riseng, C., Rutherford, E.S., Cheng, S.T., Carlson, M.L., Tyler, J.A., Stevenson, R.J., Steen, P.J., Richards, P.L., Seelbach, P.W., Koches, J.M. 2010. A Multi-Modeling Approach to Evaluating Climate and Land Use Change Impacts in a Great Lakes River Basin. Hydrobiologia 657: 243-262. DOI 10.1007/s10750-010-0239-2

Radioactive Waste Management Associates

Memo

To: Tracy Carluccio

From: Marvin Resnikoff, Ph.D.

Date: February 19, 2018

Re: DRBC Comments

General Comments

While I support the Delaware River Basin Commission's (DRBC) prohibition on high-volume hydraulic fracturing (fracking), I do not support the proposed regulations of Part 440 that allow the import of radioactive waste and solids from fracking into the basin. To be clear, the oil and gas industry has a problem in disposing of fracking water and rock cuttings. To frack a well, approximately 5 to more than 11 million gallons of water are required; in 2017 the average volume of water used to frack a Marcellus Shale well in Pennsylvania was 11.4 million gallons.[1] That is primarily because of the longer well bores, increased now from 1 - 2 miles to 4 miles or more in some areas. Some of this drilling fluid can be recycled. But there are not enough deep disposal wells to accommodate the demand for the volume of fracking water produced. As a result, the oil and gas industry has pressured the DRBC to accept this contaminated water. Under Parts 400 the DRBC has proposed regulations for the acceptance of water from fracking and placed conditions on that acceptance. Just to be clear the DRBC could simply ban the importation of fracking water and rock cuttings, but instead have established regulations that allow that to proceed. The following specific comments are in support of some of the regulations DRBC has proposed and opposes others.

We support the commission's policy of no measurable change in existing water quality. But we strongly oppose approving centralized water treatment facilities.

Specific Comments

1. To review, the process of hydraulic fracturing consists of drilling a well down to the Marcellus shale formation 4000 to 8000 feet below ground and then extending the well

[1] http://fracfocus.org/data-download

horizontally in the shale formation for up to a mile, in some cases, up to 4 miles. Casings are constructed and the wells are placed under hydraulic pressure. Explosives shatter the shale formation and proppants maintain open the shattered shale formation. When the hydraulic pressure is released much of the contaminated water, consisting of drilling fluid and interstitial water along with rock cuttings (with the consistency of coarse sand) comes to the surface. This contaminated water is stored in an adjacent pond or in tank cars. After approximately two weeks, some of the remaining water continues to come up with natural gas. This salty water (brine) is highly radioactive and is separated from natural gas at the well surface and placed into condensate tanks or trucks. This produced water or brine contains high concentrations of total dissolved solids (TDS). As shown in the table below, the TDS concentrations increase over time. The TDS concentrations can range up to 345,000 mg/L by day 90 after the well is placed into production. At the present time flowback and production water is transported to a centralized water treatment facility (CWT). After processing, the rock cuttings and sludge are disposed in sanitary landfills and processed water is released to the environment. Under the proposed regulations the rock cuttings, sludges and processed water can be transported to the Delaware River basin and may be released to accessible waterways. The proposed DRBC regulations do not prohibit disposal of rock cuttings into landfills within the basin.

It has been known for over 50 years that the Marcellus shale formation is radioactive. In the late 1970s the USGS investigated the Marcellus shale for high concentrations of uranium. So clearly what is radioactive below ground does not become non- radioactive above ground; this is not alchemy where the radioactivity simply disappears. This radioactivity, consisting of radium-226 and 228 and decay products, is a problem faced by the DRBC in establishing regulations. Because all this radioactivity must go somewhere, the DRBC is essentially establishing regulations that set the radioactive concentrations that can enter the environment within the Delaware River Watershed.

2. We support some sections of the proposed regulations. We support section 440.3 which prohibits fracking within the Delaware River basin. This is important, not only for the potential release of drilling fluids and contaminated water into aquifers but also for minimizing the potential release of the radioactive inert gas radon. We also support the policy of the commission, section 440.5, that there be no measurable change in existing water quality and that the release should not create a menace to public health and safety at the point of discharge. Based on this policy, it is inconsistent that the commission will allow produced water and wastewater from central waste treatment facilities, even under regulated conditions.

3. To be clear, the reason the DRBC and the public are going through this regulatory process is because there is not sufficient deepwell disposal capacity to handle all the contaminated water that has been brought to the surface in Pennsylvania and West

Virginia. While there are well-known methods for removing or concentrating dissolved radium and disposing the solids at a licensed facility in Utah, these methods are more costly than releasing these contaminated liquids and solids directly into landfills, streams or deep wells.

Table 1. TDS (mg/L) as a Function of Time After Well Hydraulic Fractured[2]

Location	Day 0*	Day 1	Day 5	Day 14	Day 90
A	990	15,400	54,800	105,000	216,000
B	27,800	22,400	87,800	112,000	194,000
C	719	24,700	61,900	110,000	267,000
D	1,410	9,020	40,700		155,000
E	5,910	28,900	55,100	124,000	
F	462	61,200	116,000	157,000	
G	1,920	74,600	125,000	169,000	
H	7,080	19,200	150,000	206,000	345,000
I	265	122,000	238,000	261,000	
J	4,840	5,090	48,700	19,100	
K	804	18,600	39,400	3,010	
L	221	20,400	72,700	109,000	
M	371			228,000	
N	735	31,800	116,000		
O	2,670	17,400	125,000	186,000	
P	401	11,600	78,600	63,900	
Q	311	16,600	38,500	120,000	
R	481	15,100	46,900	20,900	
S	280	680	58,300	124,000	

* Day 0 sample was taken of the influent water plus additives without sand.

4. Centralized waste treatment facilities are not a panacea. Studies by the Pennsylvania Department of Radiation Protection show that concentrations of dissolved radium that enter a CWT are approximately equal to concentrations that leave a CWT[3]. Though there are methods for removing radium from water (methods have been used extensively in uranium mills), the process is more expensive than simply releasing this contamination to the environment or into a deep well. Even if CWT's were effective, what would be the final disposal solution for sludges and solids that were created? Essentially the radium dissolved in water would be converted to a solid that can be filtered. And what would be the final disposal solution for the rock cuttings? The radioactive content of the rock cuttings ranges from 30 pCi per gram to 204 pCi per gram (the radioactive concentration of rock cuttings that were sent to the Allied landfill in Niagara County New York)[4]. Released to waterways, Duke University scientists have measured radium concentrations and stream sediments at the point of discharge 200 times greater than upstream and background sediments and above radioactive waste

[2] Veil, J, "Overview of Shale Gas Water Issues," WEFTEC 2012, New Orleans, LA, October 2012.
[3] The DEP study showed that high Ra-226 effluent releases from CWT's were 26,000 pCi/L (DEP,ES-22) equal to the high Ra-226 concentrations into the CWT's and indicating that Ra-226 was not removed at the CWT's.
[4] NYSDEC, Division of Environmental Remediation, August 2012, re. Allied Landfill, Niagara County.

disposal threshold regulations. So we are mystified by what the commission is going to find in these treatability studies required in section 440.5.

5. Under the proposed DRBC regulations, TDS shall not exceed 500 mg/L or less in all but the estuary but as mentioned earlier, the TDS can be as high as 345,000 mg/L so it's unlikely that central waste treatment facilities are going to be able to reach concentrations as low as 500 mg/L.

6. The commission also states that effluent shall not exceed the more stringent of EPA or the host states primary drinking water standards. For combined radium 226 and 228, the drinking water standard is 5 pCi per liter. Produced water can contain concentrations up to 25,000 pCi per liter. It will be difficult to reach concentrations as low as 5 pCi/L.

7. It is important to reiterate that the commission will require that any releases should not exceed background concentrations. To do that the commission must require that background concentrations first be measured. The choice of a laboratory that carries out these measurements is important. The laboratory must be reliable and EPA-certified, and not connected with the gas and oil industry.

STEPHEN P. KUNZ

Senior Ecologist, *Schmid & Company, Inc., Consulting Ecologists*
1201 Cedar Grove Road, Media, PA 19063-1044
610-356-1416 *www.schmidco.com* spkunz@aol.com

EDUCATION

B.S. Human Ecology, Cook College - Rutgers University
New Brunswick, New Jersey, 1977 (summa cum laude)

CERTIFICATIONS

Ecological Society of America: *Senior Ecologist* (2013, 2008, 2003, 1998)
Society of Wetland Scientists: *Professional Wetland Scientist* (2017, 2012, 2007, 1995)
Army Corps of Engineers: *Wetland Delineator* (Provisional Certification, Baltimore District - Certificate No. DCP93MDO51OO35B)

SUMMARY OF EXPERIENCE

Mr. Kunz has worked full-time as a private sector ecological consultant for more than three decades. His primary focus has been on water quality and wetland issues. Mr. Kunz routinely deals with state and federal water quality laws and regulations on projects throughout Pennsylvania, New Jersey, and eastern New York. He has extensive experience in the technical evaluation and regulatory review of development projects, primarily focusing on wetland delineation, assessment, and regulatory analysis.

He is experienced in the full range of field techniques in relation to wetland boundary determination, environmental inventory, and impact assessment. He has assisted in the design and implementation of numerous successful wetland mitigation projects. He has provided public testimony on specific projects. He has provided public commentary on a range of issues including proposed federal and state environmental regulations, hydric soil criteria and indicators, wetland delineation methodologies, and impacts from fossil fuel extraction.

1997-PRESENT SENIOR ECOLOGIST, SCHMID & COMPANY, INC. (MEDIA PA)
1985-1997 ECOLOGIST, SCHMID & COMPANY, INC. (MEDIA PA)

Mr. Kunz's primary responsibilities include project management, wetland delineation and assessment, regulatory review and analysis, preparation of environmental permit applications, client coordination, and report writing and editorial review on projects where property is proposed for development, purchase or sale, or preservation. His responsibilities also include staff training and supervision, public and expert testimony, and the design and implementation of wetland mitigation projects.

1982-1985 ENVIRONMENTAL SCIENTIST, SCHMID & COMPANY (MEDIA PA)

Mr. Kunz was responsible for fieldwork, technical analysis, and report preparation on projects and sites requiring wetland identification and analysis. He also assisted in the preparation of environmental assessments and permit applications.

1981-1982 ENVIRONMENTAL PLANNER, TERA CORPORATION (KING OF PRUSSIA PA)

Mr. Kunz was involved in the preparation of EIS's on proposed developments in Maryland and New York. He was responsible for mapping, data compilation, and data analysis on a major railroad siting and alternatives study. He participated in the development of computer-based programs for interactive graphics.

1979-1981 PLANNER, WAPORA, INC. (BERWYN PA)

Mr. Kunz participated in numerous environmental assessments and impact reports throughout the middle Atlantic states. He conducted land use analyses requiring preparation of land use inventory maps, calculation of environmental carrying capacity, development of future land use scenarios, and evaluation of land management codes and regulations.

1978-1979 SOCIOECONOMIST, JACK MCCORMICK & ASSOCIATES, INC. (BERWYN PA)

Mr. Kunz collected and analyzed demographic and socioeconomic data for the preparation of environmental impact statements dealing with regional wastewater facility projects in southeastern PA and MD, and with proposed coal mining activities in WV. He coordinated with federal, state, regional, and local agencies to identify their planning-related programs, policies, and regulations.

PROFESSIONAL AFFILIATIONS

Ecological Society of America (Certified *Senior Ecologist*)
New Jersey Academy of Science
Pennsylvania Academy of Science
Society for Human Ecology
Society of Wetland Scientists (Certified *Professional Wetland Scientist*)
Wetland Journal (Review Board 1999-2001)

CIVIC AFFILIATIONS

Schuylkill Township (PA) Environmental Advisory Council
Pennsylvania Campaign for Clean Water - Exceptional Value (PA-CCWEV) Workgroup

OTHER ACTIVITIES

Technical Review, *Protecting Pennsylvania' s Cleanest Streams: A Review of Pennsylvania's Antidegradation Policies and Program with Recommendations for Improvements*. Prepared by the Delaware Riverkeeper Network, July 2011.

RECENT REPORTS: PRINCIPAL AUTHOR OR COAUTHOR (2007-2018)

Kunz, Stephen P. 2018. Comments on Scope of Work for 5th Act 54 Five-Year Assessment. Prepared for Citizens Coal Council, Canonsburg, PA. Media PA. 15 p.

Schmid & Company, Inc. 2017a. Stream protection in Pennsylvania in the context of underground coal mining. Prepared for Citizens Coal Council, Canonsburg, PA. Media PA. 30 p.

Kunz, Stephen P. 2017b. Comments on "Definition of Waters of the United States" - Recodification of Pre-existing Rules, Docket ID No. EPA-HQ-OW-2017-0203. Submitted to US Environmental Protection Agency, Washington DC. Schmid & Company, Inc., Media PA. 3 p.

Schmid & Company, Inc. 2017c. Potential impacts of the Atlantic Sunrise pipeline on exceptional value wetlands and special protection waters in Schuylkill County, Pennsylvania. Prepared for Delaware Riverkeeper Network, Bristol, PA, and Schuylkill Pipeline Awareness, Schuylkill County, PA. Media PA. 21 p.

Schmid & Company, Inc. 2017d. Potential impacts of Mariner East II pipelines on wetlands, streams, and water supplies in Middletown Township and Delaware County, Pennsylvania. Prepared for Middletown Coalition for Community Safety. Media PA. 18 p.

Schmid & Company, Inc. 2017e. A comparison of the water resource impacts associated with alternative alignments of the proposed Atlantic Sunrise pipeline on and near the Nesbitt property, Luzerne and Wyoming Counties, Pennsylvania. Prepared for Icarus Ecological Services, Inc., Saint Augustine, FL. Media PA. 23 p.

Schmid & Company, Inc. 2016a. Comments on FERC DEIS for PennEast Pipeline Project in New Jersey. Prepared for the Delaware Riverkeeper Network, Bristol, PA. Media PA. 15 p.

Schmid & Company, Inc. 2016b. The effects of the proposed PennEast pipeline on exceptional value wetlands in Pennsylvania. Prepared for the Delaware Riverkeeper Network, Bristol, PA. Media PA. 54 p.

Kunz, Stephen P. 2016c. Comments on the proposal to reissue and modify nationwide permits, Docket No. COE-2015-0017. Submitted to US Army Corps of Engineers, Washington DC. Schmid & Company, Inc., Media PA. 5 p.

Schmid & Company, Inc. 2016d. Wetland and stream impacts of Sunoco's Mariner East II pipeline. Prepared for Mountain Watershed Association and the Clean Air Council. Media PA. 22 p.

Schmid & Company, Inc. 2016e. Longwall mining A to Z: learning from the Pennsylvania experience. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 56 p.

Schmid & Company, Inc. 2015a. Undermining the public trust: a review and analysis of PADEP's Fourth Act 54 Five-year Assessment report. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 67 p.

Schmid & Company, Inc. 2015b. Regulated waters and wetlands at the Fairview Golf Redevelopment site, Ridley Township, Delaware County, Pennsylvania. Prepared for Everest EB-5 Capital LLC, Havertown, Pennsylvania. Media PA. 46 p.

Schmid & Company, Inc. 2015c. Comments to the Office of Surface Mining Reclamation and Enforcement regarding the Proposed Stream Protection Rule, Docket # OSM–2010–0018. Prepared for Foundation for Pennsylvania Watersheds, Alexandria PA. Media PA. 36 p.

Schmid & Company, Inc. 2014a. The illusion of environmental protection: permitting longwall coal mines in Pennsylvania. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 138 p.

Schmid & Company, Inc. 2014b. PADEP Regulatory Jurisdiction at Green Pond/Traditions of America Site, Bethlehem Township, Northampton County, PA. Prepared for savegreenpond.org. Media PA. 64 p.

Schmid & Company, Inc. 2014c. Petition to [Pennsylvania] Environmental Quality Board for redesignation of the Upper Browns Creek watershed, Greene County, Pennsylvania. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 69 p.

Stout, Benjamin M. III, Ph.D., and Schmid & Company, Inc. 2013a. Biological assessment of Stony Run, Springfield Township, Fayette County, Pennsylvania. Prepared for University of Pittsburgh Environmental Law Clinic on behalf of Youghiogheny Riverkeeper and Mountain Watershed Association. 18 p.

Kunz, Stephen P. 2013b. Public comments presented at PADEP Citizens Advisory Council public meeting, 19 February 2013. Schmid & Company , Inc., Media PA. 5 p.

Schmid & Company, Inc. 2013c. Existing conditions at a site along Dey Road; Block 25, Lot 5; Cranbury Township, Middlesex County, NJ. Prepared in conjunction with an application to NJDEP to confirm wetlands and waters at the subject property. Media, PA. 41 p.

Schmid & Company, Inc. 2013d. Review of permit applications of Amerikohl Mining Inc. for proposed Walters Mine, Donegal Township, Butler County, Pennsylvania. Prepared for Citizens Coal Council, Bridgeville PA. Media PA. 35 p.

Schmid & Company, Inc. 2012. Independent technical review of proposed Donegal Mine, Donegal Township, Butler County, Pennsylvania. Prepared for PADEP Office of Active and Abandoned Mine Operations, on behalf of Rosebud Mining Company. Media, PA. 72 p.

Kunz, Stephen P. 2012. Comments to Thomas Callaghan, Director, PADEP Bureau of Mining Programs, on proposed Master Agreement with University of Pittsburgh to prepare the Fourth Act 54 Five-Year Review Report. Schmid & Company, Inc., Media, PA 11 p.

Schmid & Company, Inc. 2012. Delineated wetlands and streams in eastern meadows at Longwood Gardens, Kennett, Pennsbury, and East Marlborough Townships, Chester County, Pennsylvania. Submitted to Philadelphia District Army Corps of Engineers on behalf of Bancroft Engineering and Longwood Gardens. Media, PA. 48 p.

Schmid & Company, Inc. 2012. Comments to PADEP Division of Dam Safety on Dam Safety Permit Applications D30-079 and D30-080 for proposed Foundation Mine, Center and Jackson Townships, Greene County, Pennsylvania. Media, PA. 11 p.

Schmid & Company, Inc. 2012. Application to NJDEP for Individual Freshwater Wetland Permit for Lot 2, Block 2301, Paramus Borough, Bergen County, NJ. Submitted on behalf of George Washington Memorial Park Cemetery Association (landowner). Media PA. 48 p.

Schmid & Company, Inc. 2012. Comments to Pittsburgh District Army Corps of Engineers on Application CELRP-OP-F 2007-891 for proposed Foundation Mine. Center and Jackson Townships, Greene County, PA. Media PA. 17 p.

Kunz, Stephen P. 2011. Comments on Dam Safety and Encroachments Act Permit Application E5729-014 (for proposed waterlines extending 1.8 miles across exceptional value streams and wetlands to support natural gas drilling). Submitted to PADEP Oil & Gas Management Program on behalf of the Foundation for Pennsylvania Watersheds. Schmid & Company, Inc., Media PA. 24 p.

Schmid & Company, Inc. 2011. The increasing damage from underground coal mining in Pennsylvania: a review of the third Act 54 report. Prepared for Citizens Coal Council, Washington PA. Media PA. 50 p.

Schmid & Company, Inc. 2011. Streams and wetlands on properties along Bear Mountain Road Elkland Township, Sullivan County, Pennsylvania. Prepared for Bear Mountain Landowners. Media PA. 79 p.

Schmid & Company, Inc. 2011. Application to NJDEP for Letter of Interpretation Extension for Lot 3, Block 2l002 in Old Bridge Township, Middlesex County, and Lot 2, Block 176 in Marlboro Township, Monmouth County, NJ. On behalf of David Elkouby (landowner). Media PA. 29 p.

Schmid & Company, Inc. 2011. Application to NJDEP for Letter of Interpretation Presence/Absence for Lot 2, Block 2301, in Paramus Borough, Bergen County, NJ. Submitted on behalf of George Washington Memorial Park Cemetery Association (landowner). Media PA. 48 p.

Schmid & Company, Inc. 2010. Protection of water resources from longwall mining is needed in southwestern Pennsylvania. Prepared for Citizens Coal Council, Washington PA, with support from the Sierra Club. Media PA. 195 p.

Kunz, Stephen P. 2010. Comments to Baltimore District Army Corps of Engineers on Proposal to Issue Pennsylvania State Programmatic General Permit 4. Schmid & Company, Inc., Media PA. 3 p.

Schmid & Company, Inc. 2010. A need to identify “special protection” status and apply existing use protections to certain waterways in Greene and Washington counties, Pennsylvania. Prepared for Citizens Coal Council, Washington PA. Media PA. 95 p.

Kunz, Stephen P. 2010. Comments to Pennsylvania Environmental Quality Board on Proposed Rulemaking 25 PA CODE Chapter 95 (Wastewater Treatment Requirements). Schmid & Company, Inc., Media PA. 3 p.

Schmid & Company, Inc. 2009. Review of a petition to redesignate tributaries to South Fork Tenmile Creek from HQ-WWF to WWF, Center and Jackson Townships, Greene County, Pennsylvania. Prepared for Citizens for Pennsylvania’s Future. Media PA. 28 p.

Kunz, Stephen P. 2009. Comments to the US Army Corps of Engineers on the Proposed Suspension and Modification of Nationwide Permit 21 (Surface Coal Mining Operations). Schmid & Company, Inc., Media PA. 3 p.

Schmid & Company, Inc. 2009. Application for Wetland General Permits #2, #10A, and #17 and Individual Flood Hazard Area Permit, Lot 18, Block 301; Berkeley Heights Township, Union County, NJ. Submitted on behalf of Ramesh Raman (landowner). Media PA. 65 p.

Schmid & Company, Inc. 2008. Review of a petition to redesignate Grinnage Run from HQ-WWF to WWF, South Fork Tenmile Creek basin, Gray Township and Richhill Township, Greene County, Pennsylvania. Prepared for Center for Coalfield Justice, Mountain Watershed Association, and Citizens for Pennsylvania's Future. Media PA. 26 p.

Schmid & Company, Inc. 2008. Application to NJDEP for freshwater wetland General Permits 7 and 11, Towneplace Hotel, Lot 13, Block 2301, Logan Township, Gloucester County, New Jersey. Prepared for SSN Hotel Management, LLC. Newark DE. Media PA. 52 p.

Schmid & Company, Inc. 2008. Application to NJDEP for General Permit 7 and Transition Area Averaging Waiver, Lots 2 and 3, Block 134, Town of Kearny, Hudson County, New Jersey. Prepared for Arlington Cemetery Association, Kearny NJ. Media PA. 69 p.

Kunz, Stephen P. 2008. Comments to US-EPA on the Final Environmental Impact Statement (EIS) on Excess Spoil Minimization – Stream Buffer Zones. Schmid & Company, Inc., Media PA. 7 p.

Schmid & Company, Inc. 2008. Application to NJDEP for Letter of Interpretation Extension for Lot 2.03, Block 22.010, South Brunswick Township, Middlesex County, NJ. Submitted on behalf of Country Communities, LLC (landowner). Media PA. 28 p.

Schmid & Company, Inc. 2007. An investigation of existing and historic environmental conditions at Arlington Cemetery associated with alleged NJDEP violations and a proposed resolution, Lots 2 and 3, Block 134, Town of Kearny, Hudson County, New Jersey. Prepared for Arlington Cemetery Association. Media PA. 108 p.

Schmid & Company, Inc. 2007. Wetland conditions at a site along Worthington Mill Road, Wrightstown Township, Bucks County, Pennsylvania. Prepared for Brian Bentley. Media PA. 38 p.

Schmid & Company, Inc. 2007. Wetland conditions at a site in Hatfield Township, Block 77, Montgomery County, Pennsylvania. Prepared for Hatfield 309 LLC. Media PA. 69 p.

Kunz, Stephen P. 2007. Letter to Office of Surface Mining Reclamation and Enforcement, regarding advanced notice or proposed rulemaking regarding the placement of coal combustion byproducts in active and abandoned coal mines. 13 June 2007. 2 p.

Schmid & Company, Inc. 2007. Wetland conditions at a property along US Route 9, Lots 13 and 14, Block 176, Marlboro Township, Monmouth County, New Jersey. Prepared for Seasons Real Estate of New Jersey, LLC, Hightstown, New Jersey. Media PA. 41 p.

Kunz, Stephen P. 2007. Letter to Dennis G. Rice, Office of Surface Mining Reclamation and Enforcement, regarding excess spoil, coal mine waste, and buffers for Waters of the United States. 22 October 2007. 7 p.

Schmid & Company, Inc. 2007. Application for General Permits #1, #2, and #10A; Lot 51, Block 4701; Pennsville Township, Salem County, New Jersey. Prepared for Robert Mistichelli. Media PA. 41 p.

Kunz, Stephen P. 2007. Letter to David Hartos, Office of Surface Mining Reclamation and Enforcement, regarding the Draft EIS on excess spoil minimization and stream buffer zones. 21 November 2007. 7 p.

Kunz, Stephen P. 2007. Letter to Senator Jeff Bingaman, Senate Energy and Natural Resources Committee, regarding OSM administration of SMCRA. 17 December 2007. 7 p.

Schmid & Company, Inc. 2007. Wetland conditions at a site along PA Route 309 (Bethlehem Pike) near Bergey Road, Block 76, Hatfield Township, Montgomery County, Pennsylvania. Prepared for Hatfield 309 LLC. Media PA. 42 p.

RECENT MAJOR ORAL PRESENTATIONS

Office of Surface Mining Reclamation and Enforcement, Pittsburgh PA, 16 July 2015 *(Longwall Coal Mining in the US)*

PADEP Citizens Advisory Council, Harrisburg PA, 17 March 2015 *(Undermining the Public Trust: A Review and Analysis of PADEP's Fourth Act 54 Five-Year Assessment Report)*

Pennsylvania Groundwater Symposium, Penn State University, State College, PA, 7 May 2014 (*Undocumented Groundwater Damage from Longwall Coal Mining in Pennsylvania)*

Citizens Coal Council Act 54 Strategic Meeting, Yorktowne Hotel, York PA, 26 September 2013 (*The Need to Reform Act 54*)

PADEP Citizens Advisory Council, Harrisburg PA, 20 November 2012 (*Major Concerns with Act 54 Reporting*)

Appalachian Public Interest Environmental Law Conference, Knoxville TN, 27 October 2012 (*Lessons From Regulating Longwall Coal Mining in Pennsylvania*)

Mid-Atlantic ESA Annual Meeting and Conference, Blacksburg VA, 14 April 2012 (*Increase in Aquatic Resource Impacts from Longwall Coal Mining Following Revision of Pennsylvania Underground Mining Law*)

Chester County Citizens for Climate Protection, West Chester PA, 7 December 2011 (*The Need to Reform Act 54*)

Morris Township Community Center, Nineveh PA, 22 June 2011 (*The Increasing Damage from Underground Coal Mining in Pennsylvania: A Review of the Third Act 54 Report*)

PADEP Citizens Advisory Council, Harrisburg PA, 19 April 2011 (*The Increasing Damage from Underground Coal Mining in Pennsylvania: A Review of the Third Act 54 Report*)

US Environmental Protection Agency, Philadelphia PA, 10 November 2010 (*Protection of water resources from longwall mining is needed in southwestern Pennsylvania*)

Schuylkill River Watershed Congress, Pottstown PA, 13 March 2010 (*Are "Special Protection" Waters Getting the Protection they Deserve?)*

JAMES A. SCHMID

EDUCATION

Ph.D., Geography, University of Chicago, 1972
M.A., Geography, University of Chicago, 1969
A.B., Geography, Columbia College, Columbia University, 1966

CERTIFICATIONS

Ecological Society of America: Senior Ecologist (1983; recertified 1988, 1993, 1999, 2008, 2014)
Society of Wetland Scientists: Professional Wetland Scientist #284 (1995; recertified 2007, 2012)
US Army Corps of Engineers, Baltimore District: Wetland Delineator Program (Provisional Certification #93MD0310008A)
US Fish & Wildlife Service: Habitat Evaluation Procedures (HEP 1981)

CONTACT INFORMATION

Phone:	(610) 356 - 1416	Email:	jaschmid@aol.com
Fax:	(610) 356 - 3629	Web Page:	www.schmidco.com

Schmid & Co., Inc., Consulting Ecologists 1201 Cedar Grove Road Media PA 19063-1044

SUMMARY OF EXPERIENCE

1985- **President, Schmid & Company, Inc.**, Consulting Ecologists. Dr. Schmid's current responsibilities include fieldwork, administration of contracts, writing and editing reports, regulatory analysis, client representation before agencies, expert testimony in court and at hearings, and overall management of the firm.

1981-1985 **Principal, Schmid & Company**, Consulting Ecologists. Dr. Schmid was responsible for fieldwork, project management, consultation with clients and regulatory agency personnel, the preparation and delivery of testimony in court and at public meetings, and the technical and editorial supervision of multidisciplinary reports.

1981-1982 **Principal Environmental Scientist, TERA Corporation.** Dr. Schmid provided technical supervision for a major environmental impact statement on alternative railroads in Niagara County, New York, and managed analyses of wetland fill and mitigation proposed in the New York and Philadelphia metropolitan areas and in the New Jersey Pine Barrens. He also worked on lignite mining projects in the Red River basin of western Louisiana.

1979-1981 **Principal Scientist, WAPORA, Inc.** Dr. Schmid supervised a statewide impact assessment of coal mining in Appalachia for the Environmental Protection Agency and provided technical direction for seven areawide environmental assessments of future coal mining in West Virginia. He managed impact statements for oil and coal terminals and prepared an extensive report on coastal zone management for the New Jersey Department of Environmental Protection. He also served as senior technical advisor on projects in the Mississippi River basin, the eastern Kentucky coal fields, and the Texas Gulf Coast.

1973-1979 **Chairman of the New York office (1973-1974) and Vice President, Jack McCormick & Associates, Inc., Pennsylvania office** (1974-1979). Dr. Schmid managed environmental assessments and reports on proposed residential, industrial, and commercial developments at Brigantine, Secaucus, East Rutherford, North Bergen, Hoboken, and Camden, New Jersey; Philadelphia, Pennsylvania; and Beachville, Maryland. He directed inventories and analyses of the Fire Island National Seashore for the National Park Service and of the New York Bight for the National Oceanic and Atmospheric Administration. He designed and implemented a major analysis of environmental regulations and their effects on private industry for the US Department of Commerce and the President's Council on Environmental Quality.

1970-1973 **Assistant Professor and Instructor in the Department of Biological Sciences, Barnard College and Columbia University.** Dr. Schmid taught graduate and undergraduate courses in ecology, biogeography, environmental science, and cultural geography. His prime research interests were in the environmental effects of urbanization, the role of vegetation in cities, and the conceptualization and quality control of environmental assessments.

1968-1970 He served as **technical editor for research papers in the Department of Geography at the University of Chicago**.

Dr. Schmid has been a **guest lecturer on environmental analysis and wetlands at the University of Pennsylvania, Columbia University, Cabrini College, Clark University, West Chester State University, Rutgers University,** and the **Delaware County Community College**. He has often addressed wetland issues at the Polley Associates School of Real Estate. He has served on the Standing Committee on Environmental Education for the Association of American Geographers and has contributed reviews to the *Geographical Review* and to *Ecology*. He has served on the Board of Professional Certification of the Ecological Society of America and on the Certification Standards Committee of the Society of Wetland Scientists Professional Certification Program, Inc. For many years he served on the Environmental Advisory Board of Marple Township, Delaware County, Pennsylvania. He has peer reviewed journal articles for *Wetlands* and grant proposals submitted to the National Science Foundation, the US Department of State, and the National Geographic Society. Dr. Schmid has served as the elected president of the Chester County Beekeepers Association.

HONORS AND AWARDS

Columbia College Scholarship
Columbia College Phi Beta Kappa
A.B. cum *laude*, Columbia College, Columbia University
NDEA Title VI fellowship awards (U. Chicago, U. Wisconsin at Madison, U. Washington at Seattle, Johns Hopkins U.)
American Men of Science
Gubernatorial appointment to Pennsylvania Department of Environmental Protection's Citizens Advisory Council

PROFESSIONAL AFFILIATIONS

American Association for the Advancement of Science
Association of American Geographers
Association of State Wetland Managers
Ecological Society of America
New Jersey Academy of Science
New York State Wetlands Forum, Inc.
Society of Wetland Scientists

PROJECT EXPERIENCE

Dr. Schmid's career in environmental analysis began in the late 1960s. He has worked for all types of clients, including federal agencies, state agencies, municipalities, private developers, utilities, conservation groups, attorneys, architects, and engineering firms on many kinds of assignments.

While on the faculty of Biological Sciences at Columbia University, Dr. Schmid introduced students to the ecology of the New York-New Jersey metropolitan area and the New Jersey Pine Barrens. His scholarly research focuses on urban vegetation and historic changes in vegetation affected by human activity. His first environmental impact assessment and recommendations for minimizing impacts were prepared for a developer while he was still a graduate student and dealt with a proposed residential subdivision in the Thorn Creek Woods of suburban Will County, Illinois.

During his graduate studies in plant ecology at the University of Chicago, Dr. Schmid became familiar with the bogs and floodplain vegetation of northern Illinois, northern Indiana, and southern Michigan. While a visiting graduate student at the University of California at Los Angeles, he worked on the flora of the Mojave Desert and Santa Monica Mountains of southern California with Mildred Mathias, and he accompanied Jonathan Sauer on a flora collecting expedition to San Clemente Island. He helped Monte Lloyd collect periodic cicadas in Illinois, Ohio, and West Virginia. His master's thesis dealt with historic vegetation change in the subhumid to semi-arid limestone Edwards Plateau of southcentral Texas.

During his six years as Project Manager and Vice President at Jack McCormick & Associates, Dr. Schmid was closely associated with the late Dr. McCormick (a nationally recognized authority on wetlands and environmental assessment), both in field analyses and in project planning aimed at preserving, enhancing, restoring, or creating wetland ecosystems.

Dr. Schmid has participated in more than 100 environmental impact statements prepared using Federal, State, or local guidelines. He wrote a major analysis of the effects of the National Environmental Policy Act and Federal EISs on private industry for the US Department of Commerce, and conducted a follow-on seminar sponsored by the Council on Environmental Quality and the American Management

Association. He prepared a shortened version of the report for distribution by the Commerce Department and the Business Roundtable. As senior scientist he worked on diverse projects in Maine, West Virginia, Kentucky, Illinois, Iowa, Texas, Louisiana, Washington State, and Pacific coastal Nicaragua, not to mention the mid-Atlantic States. He participated in several wastewater treatment system EISs in suburban Philadelphia, suburban Baltimore, and at Oakwood Beach, Staten Island.

In the Hackensack Meadowlands of New Jersey, Dr. Schmid was responsible for the analyses and negotiations that led to issuance of major Federal and State permits (Clean Water Act Section 404) to fill wetlands and the Hackensack River at the Harmon Cove residential development (96 acres) and for compliance monitoring at the New Jersey Sports Complex (federal permit, 35 acres; State permit, 250 acres of tidal and non-tidal wetlands). He also was involved with assessments of a proposed new freeway (US 1 & 9), the initial Hartz Mountain Harmon Meadows Tract shopping and residential development proposal, the redevelopment of a city park (Lincoln Park West) in Jersey City, and a plan for wetlands enhancement in connection with a proposed sand and gravel operation in North Bergen. He was responsible for environmental studies, mitigation plans, and technical negotiations that led to issuance of a major Corps permit to fill 127 acres of marsh with compensation by enhancing 151 acres. He recently analyzed historic land use activities at a cemetery at the edge of the Meadowlands to ascertain the extent of wetland violations and aid the landowner in attaining compliance with NJDEP requirements.

Dr. Schmid directed a comprehensive inventory of Fire Island National Seashore in Suffolk County, New York, for the National Park Service. In New Jersey, he assisted Dr. McCormick in designing satisfactory restoration leading to permits for filling 11 acres for development in the southernmost section of Brigantine Island facing Atlantic City. In New Jersey he has worked on several analyses of beach protection and the effects of altering sand dunes, a major concern also at Fire Island National Seashore. He has participated in numerous wetland permit applications and resolution of enforcement cases in Staten Island and Brooklyn.

Dr. Schmid wrote a Federal EIS on a proposed fuel oil transfer and storage terminal in the Hudson River under contract to the New York District of the Army Corps of Engineers. Dr. Schmid also was responsible for coastal wetland projects along the Shark River, at Ocean City, and along Barnegat Bay. He supervised an analysis of the freshwater tidal marsh at Fish House Cove on the Delaware River for the Camden County Environmental Agency and a comprehensive review of proposed development in salt marshes along a barrier beach in Sussex County, Delaware, for the Delaware Department of Natural Resources and Environmental Control. Dr. Schmid supervised evaluations of several marshes along Delaware Bay in New Jersey and Delaware for National Natural Landmark status on behalf of the National Park Service.

His extensive analysis of coastal zone management in New Jersey, with a detailed account of the administration of the (Tidal) Wetlands Act and other wetland regulations, formed a major part of a four-volume Estuarine Study submitted to the New Jersey Department of Environmental Protection in 1979. Dr. Schmid managed a residential development analysis near the mouth of the Potomac River at Beachville, Maryland, and he wrote the foreword to Dr. McCormick's monumental report on the coastal wetlands of Maryland at the request of the Maryland Department of Natural Resources.

Dr. Schmid has represented developers in regulatory negotiations concerning wetlands at Bethany Beach, Delaware; near the mouth of the Raritan River for a major new town associated with New Jersey's largest industrial park; in Gloucester City, New Jersey, where a freshwater tidal marsh was restored; at the DuPont Chambers Works, a major chemical plant adjacent to the Delaware River in Salem County, New Jersey; and in Bucks County, Pennsylvania, where a waterfront slag plant was proposed. He successfully designed mitigation for a major marine container terminal expansion, which entailed the filling of 16 acres in the Delaware River and 8 acres of freshwater tidal marsh and oversaw the restoration of a tidal marsh on the Neshaminy Creek. He has achieved full success in all of his wetland restoration and creation projects.

For the National Oceanic and Atmospheric Administration Dr. Schmid assembled a multidisciplinary panel to establish priority chemical contaminants of the New York Bight. This report formed the basis for funding by NOAA of research on chemicals in the 15,000 square miles of ocean waters off New York and New Jersey.

Dr. Schmid has worked on behalf of developers, environmental groups, and regulatory agencies in the Pinelands of southern New Jersey. Dr. Schmid's analyses enabled the New Jersey Pinelands Commission to approve development on a site with 355 acres of wetlands in Burlington County for more than 2,500 housing units under a hardship application. He assembled a review of vegetation and critical areas mapping in the Pinelands on behalf of a developer near Mays Landing. He wrote a critique of the Pinelands Commission's inventory mapping for the Sierra Club, and he defended a developer and the Pinelands Commission in a challenge to a regulatory decision approving a residential project. He represented the New Jersey Conservation Foundation, Environmental Defense Fund, and other conservation groups challenging a Pinelands Commission hardship waiver on a major residential development. He also supervised a critique of the proposed USEPA designation of a sole-source aquifer in southern New Jersey on behalf of the South Jersey Homebuilders Association. He analyzed the significance of potential impacts on wetlands and other resources by railroad construction in upstate New York under a third-party agreement to produce the major Federal EIS which preceded project approval.

Dr. Schmid assisted in an evaluation of development adjacent to the Tannersville Bog in Monroe County, Pennsylvania, on behalf of The Nature Conservancy. He demonstrated that a proposed nearby housing development posed no threat to the National Landmark bog. He has worked on other wetlands at several locations in the

Poconos where delineations and permit approvals were necessary. He oversaw a National Natural Landmarks evaluation of the Great Piece Meadows in northern New Jersey for the National Park Service and an assessment of impacts from regional sewer construction on the Great Swamp of the upper Passaic River for the US Environmental Protection Agency.

He supervised analyses of proposed development around Lake Valhalla in Morris County, and his testimony helped Montville Township zoning withstand challenge and appeal through the New Jersey court system. He managed the successful technical defense of a highway contractor, accused of polluting Lake Saginaw in Sussex County, New Jersey, with sediment, on behalf of Liberty Mutual Insurance Company. In Morris County he oversaw wetland boundary mapping on a 200+ acre tract and successfully defended the mapping through agency review and intervenor challenge. His project work has taken him to most of the major wetlands in the Passaic River Basin of northern New Jersey: Great Piece Meadows, Troy Meadows, Bog and Vly Meadows, Black Meadow, and Hatfield Swamp.

In Pennsylvania Dr. Schmid has supervised permitting for numerous residential, industrial, and commercial developments including landfills and shopping malls. He analyzed impacts and prepared reports and expert testimony on the impacts of coal mines, surface mines, fiber-optic cables, water wells, and residential subdivisions for various clients including the Izaak Walton League of New Jersey, the Raymond Proffitt Foundation, the Delaware Riverkeeper, the Center for Coalfield Justice, the Mountain Watershed Association, and the Green Valleys Association. He prepared the wetland-related sections of the Crum Creek Rivers Conservation Plan for the Department of Conservation and Natural Resources. He has examined a number of sites for rare species such as bog turtle and beach plum.

Dr. Schmid's principal expertise and professional interest lie in the analysis of urban vegetation and in the design and establishment of functioning ecosystems in the form of new wetlands, reclaimed landfills, mined areas, and other vegetated spaces in the increasingly human-dominated environment. Under his supervision, Schmid & Company has participated in many hundreds of wetland projects throughout New Jersey, Pennsylvania, and New York State, as well as projects in other States.

When the US Fish & Wildlife Service Pleasantville Office evaluated actual compliance with approval conditions by all the Clean Water Act Section 404 fill permits issued by the Corps of Engineers in the State of New Jersey during the period 1985-1992, every Schmid & Company mitigation project was judged in the field to exhibit full compliance with all requirements and mitigation goals. Schmid & Company mitigation projects represented 21% of all the mitigation projects judged fully successful in New Jersey by USFWS in its written report to USEPA.

PUBLICATIONS

ACADEMIC RESEARCH

<u>Doctoral Dissertation</u>: Urban vegetation, a review and Chicago case study. University of Chicago, Department of Geography (published in full; see below).

<u>Masters Thesis</u>: The wild landscape of the Edwards Plateau of southcentral Texas: a study of developing livelihood patterns and ecological change. University of Chicago, Department of Geography. 1969. 144 p.

BOOKS

Schmid, James A. 2003. Checklist and synonymy of Maryland higher plants, with special reference to their rarity, protected, and wetland indicator status. First edition. Schmid & Company, Inc. Media PA. 406 p.

Schmid, James A. 2003. Checklist and synonymy of Delaware higher plants, with special reference to their rarity and wetland indicator status. First edition. Schmid & Company, Inc. Media PA. 302 p.

Schmid, James A. 2003. Checklist and synonymy of New York higher plants, with special reference to their protective, rarity, and wetland indicator status. First edition. Schmid & Company, Inc. Media PA. 460 p.

Schmid, James A. 2001. Checklist and synonymy of New Jersey higher plants, with special reference to their rarity and wetland indicator status. Third edition. Schmid & Company, Inc. Media PA. 325 p.

Schmid, James A. 2001. Checklist and synonymy of Pennsylvania higher plants, with special reference to their rarity and wetland indicator status. Second edition. Schmid & Company, Inc. Media PA. 365 p.

Schmid, James A. 1994. Checklist and synonymy of New Jersey higher plants with special reference to their rarity and wetland indicator status: Volume I field manual. Second edition. Schmid & Company, Inc. Media, PA. 17O p.

Schmid, James A., and John T. Kartesz. 1994. Checklist and synonymy of New Jersey and Pennsylvania higher plants with special reference to their rarity and wetland indicator status: Volume II desk manual. First edition. Schmid & Company, Inc. Media, PA. 443 p. (Reviewed by: Kraus, M. 1995. Wetland Journal 7(1):21.)

Schmid, James A. 1994. Checklist and synonymy of Pennsylvania higher plants with special reference to their rarity and wetland indicator status: Volume I field manual. First edition. Schmid & Company, Inc. Media, PA. 182 p.

Schmid, James A. 1990. Checklist and synonymy of New Jersey higher plants with special reference to their rarity and wetland indicator status. First edition. Schmid & Company, Inc. Media, PA. 2 vols. (247 + 177 p.)

Schmid, James A. 1975. Urban Vegetation: a review and Chicago case study. Department of Geography, University of Chicago, Research Paper 161. Chicago IL., 266 p.

REVIEWED BY:

Küchler, A.W. 1976. Bioscience 26(7):454.
de Laubenfels, D.B. 1976. Geographical Review 66(3):370-71.
Barkham, J.P. 1976. Journal of Ecology 64(3):1113.
Haefner, H. 1977. Geographica Helvetica, p.53.
Wagner, P.L. 1977. Annals of the Association of American Geographers 67(1):171-73.
Levenson, J.B. 1977. Ecology 58(2):465.
Gutte, P. 1978. Petermanns Geographische Mitteilungen (1):56.
T., J. 1978. Annales de Géographie (481):382.

PROFESSIONAL PAPERS AND BOOK CHAPTERS

Schmid, James A. 2007. Draft Atlantic and Gulf coastal plain regional supplement to the 1987 Wetland Delineation Manual. The Forum 14(1):5, 8, 11. New York State Wetlands Forum, Inc.

Schmid, James A. 2005-2006. Introduced, non-native, and invasive plants in mid Atlantic woods and wetlands: is there a problem in the human habitat? The Forum 11(2) and 12(1). New York State Wetlands Forum, Inc.

Schmid, James A. 2003. Evaluating created wetlands in New Jersey: how credible is NJDEP? (Abstract). New Jersey Academy of Science Bulletin 48 (1): 28.

Schmid,James A. 2001. So you think you have hydrophytic vegetation? Wetland Journal 13(2):29-31.

Schmid, James A. 2000. Wetlands as conserved landscapes in the United States. In A. B. Murphy and D. L. Johnson, eds. Cultural Encounters with the Environment: Enduring and Evolving Geographic Themes. Rowman & Littlefield. Lanham MD. p. 133-155.

Schmid, James A. 1997. Wetland mitigation case studies. Chapter 9 in Mark S. Dennison. Wetland Mitigation. Rockville MD. Government Institutes Press. p. 157-182.

Schmid, James A. 1996. More on fire sales. National Wetlands Newsletter 18(5):4

Schmid, James A. 1996. Fire sale in Pennsylvania. National Wetlands Newsletter 18(1):4-5.

Schmid, James A. 1994. Wetlands in the urban landscape of the United States. In R. H. Platt, R. A. Rowntree, and P. C. Muick (eds.). The Ecological City: Preserving and Restoring Urban Biodiversity. University of Massachusetts Press. Amherst MA. p. 106-133.

Schmid, James A. 1994. Wetland creation using native plants. "A Preference for Natives". Proceedings of the symposium, 22 March 1991. Longwood Graduate Program, University of Delaware, Longwood Gardens. Kennett Square PA. p. 30-47.

Schmid, James A. 1989. Mitigation for fills in wetlands: the promise and some recent experience in New Jersey. (Abstract) Bulletin of the New Jersey Academy of Science 34(2):34.

Schmid, James A. 1989. Aboveground primary productivity in marshes of the Raritan River estuary, Middlesex County, NJ. (Abstract) Bulletin of the New Jersey Academy of Science 34(2):34.

Schmid, James A. 1989. Dune destruction at Normandy Shores, Dover Township, Ocean County: is NJDEP minding the shore? (Abstract) Bulletin of the New Jersey Academy of Science 34(2):34.

Schmid, James A. 1985. Atlantic whitecedar in the Hackensack Meadowlands, New Jersey: its historic extirpation and future reestablishment. In A. D. Laderman (ed.). Atlantic White Cedar Wetlands. Westview Press. Boulder CO. p. 317-322.

Schmid, James A. 1984. What and where are New Jersey's inland wetlands? (Abstract) Bulletin of the New Jersey Academy of Science 29(1):31.

Jurka, Valdis, and James A. Schmid. 1981. Contaminants in runoff from a parking structure in Northern New Jersey. (Abstract) Bulletin of the New Jersey Academy of Science 26(2):74.

Munro, John W., and James A. Schmid. 1981. Primary productivity in a backbarrier tidal marsh, northern Sussex County, Delaware. (Abstract) Bulletin of the New Jersey Academy of Science 26(2):69.

Schmid, James A. 1981. New Jersey's coastal wetlands: will they be protected? (Abstract) Bulletin of the New Jersey Academy of Science 26(2):64.

Schmid, James A. 1980. The effects of the National Environment Policy Act on corporate decision making. Early Corporate Environmental Assessment: Selected Papers. U.S.Department of Commerce, Office of Environmental Affairs. Washington DC. p. 1-9.

Schmid, James A., and David H. Dike. 1979. Biological resource information and coal mine assessment in the Gauley and Monongahela river basins, West Virginia. In Duane G. Nichols, R. A. Servais, and E. J. Ralinski (eds.). Proceedings of the Sixth National Conference on Energy and the Environment. Dayton Section, American Institute of Chemical Engineers. Dayton OH. p. 177-181.

Schmid, James A. 1979. Biological resource information and coal mine assessments in the Gauley and Monongahela river basins. Surface Mining and Fish/Wildlife Needs in the Eastern United States. U.S. Fish and Wildlife Service Publication FWS/OBS-78/81A. Washington DC. p. 87-90.

Schmid, James A. 1979. Vegetation types, functions, and constraints in metropolitan environments. Chapter 21. Planning the Uses and Management of Land. American Society of Agronomy. Madison WI. p. 499-528.

Schmid, James A. 1978. The urban habitat. In G. W. Frankie and C. S. Kohler (eds.). Perspectives in Urban Entomology. Academic Press. New York NY. p. ix-xiii.

Schmid, James A. 1977. Research and management: The case of Fire Island National Seashore. In J. H. Noyes and E. H. Zube (eds.). Coastal recreation resources in an urbanizing environment. Cooperative Extensive Service, University of Massachusetts. Amherst MA. p. 119-127.

Schmid, James A., D. Pennington, and J. McCormick. 1975. Ecological impact of the disposal of municipal sludge onto the land. Proceedings of the 1975 National Conference on Municipal Sludge Management and Disposal. Information Transfer, Inc. Rockville MD. p. 156-168.

Schmid, James A. 1974. The environmental impact of urbanization. In I. R. Manners and M. W. Mikesell (eds.). Perspectives on Environment. Association of American Geographers, Commission of College Geography Publication 13. Washington DC. p. 213-251.

Schmid, James A. 1974. The environmental impact of plants and animals. Ekistics 37(218):53-61.

LECTURES

Schmid, James A. 2015. Powerlines, pipelines, wetlands, and streams: data are critical for decisionmaking. Schuylkill Watershed Congress. Pottstown PA.

Schmid, James A. 2015. How not to design and regulate onlot residential sewage systems---someone might be paying attention. American Water Resources Association, Philadelphia Metropolitan Area Section. Philadelphia PA.

Schmid, James A. 2014. Water quality protection: a “wicked” problem in Pennsylvania. Cabrini College. Radnor PA.

Schmid, James A. 2014. To keep New York green, learn from Pennsylvania’s mistakes. New York State Wetlands Forum, Inc. Annual Meeting, Rochester NY.

Schmid, James A. 2014. Shale gas, pipelines, and rural water supplies. Pennsylvania Rural Watershed Association Annual Meeting. Harrisburg PA.

Schmid, James A. 2014. How precarious is environmental protection in Pennsylvania? Precarious Alliance Energy in Transition Symposium. Doylestown PA.

Schmid, James A. 2013. How not to protect streams and wetlands, Pennsylvania-style. Ecological Society of America Mid-Atlantic Chapter Annual Meeting. Dover DE.

Schmid, James A. 2013. Natural gas extraction and its impacts in the landscape. Fourth Annual Choose Clean Water Conference. Baltimore MD.

Schmid, James A. 2012. Wetland science versus wetland regulation: observations of a practicing ecologist. Society of Wetland Scientists Mid-Atlantic Chapter Annual Conference. New Brunswick NJ.

Schmid, James A. 2012. Let mother nature clean up our mess: an attempted misuse of science to avoid protecting streams and wetlands. Society of Wetland Scientists Mid-Atlantic Chapter Annual Conference. New Brunswick NJ.

Schmid, James A. 2012. When sorcerers’ apprentices fail to protect streams and wetlands. New York State Wetlands Forum, Inc. Annual Meeting, Utica NY.

Schmid, James A. 2011. Marcellus shale gas impacts on Pennsylvania wetlands and streams. Ecological Society of America Mid-Atlantic Chapter and New Jersey Academy of Sciences Annual Meeting. Montclair NJ.

Schmid, James A. 2011. Marcellus shale gas impacts on Pennsylvania wetlands and streams. New York State Wetlands Forum, Inc. Annual Meeting, Lake Placid NY.

Schmid, James A. 2010. Marcellus shal gas: what, where, whence, why now, so what? One ecologist’s observations. Cabrini College. Radnor PA.

Schmid, James A. 2009. Regulatory gaps in Pennsylvania headwaters stream protection. Association of American Geographers Annual Meeting. Las Vegas NV.

Schmid, James A. 2009. Searching for bog turtles in southeastern Pennsylvania. Greater Philadelphia Herpetological Society and Marple Township Environmental Advisory Board. Broomall PA.

Schmid, James A. 2009. Protecting significant headwaters in Pennsylvania: Lessons from real projects in five counties, southeast and southwest. Schuylkill Watershed Congress. Pottstown PA.

Schmid, James A. 2009. Clean coal? Impacts of longwall mining in Pennsylvania. PennEnvironment and Sierra Club of Southeastern Pennsylvania. Free Library of Philadelphia. Philadelphia PA.

Schmid, James A. 2008. Ecological and soil regions along the Atlantic coastal plain---rules for Clean Water Act wetland delineation. Association of American Geographers Annual Meeting. Boston MA.

Schmid, James A. 2007. The missing geography of wetlands in the United States. Association of American Geographers Annual Meeting. San Francisco CA.

Schmid, James A. 2006. A consulting ecologist's observations on environmental regulation in the real world---focus on the National Environmental Policy Act and wetlands protection. Columbia University, Department of Ecology, Evolution, and Environmental Biology. New York NY.

Schmid, James A. 2003. Multiple wetland boundaries on a single tract of land: when different levels of government undermine credible regulation. New York State Wetland Forum, Inc., Annual Meeting. Saratoga Springs NY.

Schmid, James A. 2002. NWI wetland indicator status---are there any significant differences between 1988 and 1997 indicators for plants in the mid Atlantic states? US Environmental Protection Agency Wetlands Workshop. Atlantic City NJ.

Schmid, James A. 2002. Rare plants, protected plants, native plants, and wetlands in the mid Atlantic states. New York State Wetlands Forum, Inc., Annual Meeting. Syracuse NY.

Schmid, James A. 2001. So you think you have hydrophytic vegetation? US Environmental Protection Agency Wetlands Workshop. Atlantic City NJ.

Schmid, James A. 2001. Calculating hydrophytic vegetation: select the method that gives you the result you want? Society of Wetland Scientists Annual Meeting. Lake Placid NY.

Schmid, James A. 2001. Assembling the plant list for New Jersey: sources of wetland indicator status information. US Environmental Protection Agency Wetlands Workshop. Atlantic City NJ.

REVIEWS

Schmid, James A. 2007. City trees: A historical geography from the Renaissance through the nineteenth century, by Henry W. Lawrence. Geographical Review 97(4):572-574.

Schmid, James A. 2001. My, how much we need to learn about wetlands! Wetland ecology: principles and conservation, by Paul A. Keddy. Ecology 82(7): 2085

Schmid, James A. 1999. Days afield: exploring wetlands in the Chesapeake Bay region, by William S. Sipple. Wetland Journal 11(4):21.

Schmid, James A. 1998. Discovering the unknown landscape: a history of America's wetlands, by Ann Vileisis. Wetland Journal 10(2): 30.

Schmid, James A. 1977. Worldwide human modification of ecosystems. Ecology 58(1):221-222.
Schmid, James A. 1977. Politics of shore erosion: Westhampton Beach, by J. M. Heikoff. Geographical Review 67(4):491-93.

SELECTED CONTRACT REPORTS

- Principal Authorship

JMA. 1974. Environmental impact assessment on the construction and operation of a residential and commercial development, Specially Planned Area I, Town of Secaucus, Hudson County, New Jersey. Submitted to the State of New Jersey, Hackensack Meadowlands Development Commission, Lyndhurst NJ, by Hartz Mountain Industries, Inc. Devon PA. 241 p.

JMA. 1975. Draft environmental impact statement on construction permits for a proposed fuel storage terminal in the Hudson River, Weehawken Cove, Hudson County, New Jersey. Prepared for the United States Army Engineer District, New York City. Devon PA. 217 plus 103 p.
JMA. 1975. Environmental inventory of the Fire Island National Seashore and the William Floyd Estate, Suffolk County, New York. Submitted to the National Park Service, Denver CO. Devon PA. 461 p. plus map folio.
JMA. 1975. The potential impact of urbanization on the fringe of megalopolis. Prepared for the Committee for the Preservation of Northern Montville, Montville NJ. Devon PA. 36 p.

JMA. 1976. Community development block grant program environmental assessment report on the Gateway Project. Prepared for the City of Camden NJ. Berwyn PA. 70 p.

JMA. 1977. Final report on environmental aspects of the new source NPDES permit program for the West Virginia surface coal mining industry, 1977-1980. Prepared for the US Environmental Protection Agency Region III, Philadelphia PA. Berwyn PA. 219 p.
JMA. 1977. Supplemental socioeconomic environmental impact assessment on the construction and operation of an Island Residential development on Specially Planned Area I, Town of Secaucus, Hudson County, New Jersey. Submitted to the State of New Jersey, Hackensack Meadowlands Development Commission, Lyndhurst NJ, by Hartz Mountain Industries, Inc. Berwyn PA. 201 p.
JMA. 1977. Effects of the National Environment Policy Act on corporate decisionmaking: A draft report for review. Prepared for the United States Department of Commerce, Washington DC. Berwyn PA. 268 p.

JMA. 1978. Draft environmental impact statement for the proposed Ravenscliff Subdivision, Radnor and Newtown Townships, Delaware County, Pennsylvania. Prepared on behalf of Ravenscliff Land Co., Devon PA, for submission to Radnor Township. Berwyn PA. 85 p.

JMA. 1979. New source NPDES permits and environmental impacts of the coal mining industry in the Monongahela and Gauley River Basins, West Virginia. Prepared for US Environmental Protection Agency Region III, Philadelphia, PA. Berwyn PA.
WAPORA. 1979. The estuarine study, Volume I, Part 3, management report and recommendations. Prepared for the New Jersey Department of Environmental Protection, Trenton NJ. Chevy Chase MD. 220 p.
WAPORA. 1979. Potential environmental impacts of energy facilities and other development on Fish House Cove, Delaware River. Prepared for Camden County Environmental Agency, Camden NJ. 78 p. plus folio map.
WAPORA. 1979. Analysis of sole source designation pursuant to Section 1424(e) of the Safe Drinking Water Act and the proposed coastal New Jersey designation. Prepared for Homebuilders League of South Jersey, Cherry Hill NJ. Berwyn PA. 39 p.
WAPORA. 1979-1980. New Jersey Sports Complex monitoring reports 59 through 66. Prepared for submission to regulatory agencies by the New Jersey Sports and Exposition Authority. Berwyn PA. (combined) 353 p.
WAPORA. 1979-1980. Quarterly reports 2 through 6 updating the 1978 Hearing Officers' Report on the construction and operation of the New Jersey Sports Complex. Prepared on behalf of the New Jersey Sports and Exposition Authority for presentation to the Environmental Liaison Committee. Berwyn PA. (combined) 68 p.
WAPORA. 1979-1980. Monthly official minutes of the Environmental Liaison Committee pertaining to the construction and operation of the New Jersey Sports Complex, East Rutherford, New Jersey. Meetings 57 through 71. Berwyn PA. (combined) 110 p. exclusive of attachments.

Munro, John W., and James A. Schmid. 1980. A technical review of vegetation, land use, and critical areas mapping in the Pinelands of New Jersey, with recommendations for enhanced resource protection and public benefit. Prepared on behalf of the New Jersey Sierra Club for submission to the New Jersey Pinelands Commission. Media PA. 45 p.

Schmid & Co. 1981. Summary review of environmental aspects of the proposed expansion of the general marine cargo terminal, Gloucester, New Jersey. Prepared for Holt Hauling & Warehousing Systems, Inc., Gloucester NJ. Media PA. 35 p.
TERA. 1981. Report on environmental conditions at Leisure Towne, Southampton Township, Burlington County, New Jersey. Prepared for Leisure Technology Inc., Lakewood NJ. King of Prussia PA. 16 p.
TERA. 1981. Environmental mitigation plan to offset the proposed loss of tidal wetlands on lands in North Bergen and Secaucus, Hackensack Meadowland District, New Jersey. Prepared for Hartz Mountain Industries, Inc., Secaucus, New Jersey. King of Prussia PA. 12 p.
TERA. 1981. Specifications for site work and revegetation, terminal expansion, and park site mitigation, Camden County, New Jersey. Prepared for Holt Hauling & Warehousing System, Inc., Gloucester NJ. King of Prussia PA. 16 p.

TERA. 1982. Draft environmental impact statement for Foxcroft, Farmbrook, Timberline Subdivisions, Frederick County, Maryland. Prepared for US Department of Housing and Urban Development, Region III. King of Prussia PA. 130 p.
TERA. 1982. Description of proposed marine terminal expansion, proposed mitigations, and assessment of compliance with coastal policies. Prepared for Holt Hauling & Warehousing Systems, Inc., Gloucester NJ, for submission to Tidelands Resource Council, Division of Coastal Resources, New Jersey Department of Environmental Protection. King of Prussia PA. 44 p.
TERA. 1982. Wetland values on the Hartz Mountain project site, Secaucus and North Bergen, Hudson County, New Jersey. Prepared for Hartz Mountain Industries, Inc., Secaucus NJ. King of Prussia PA. 59 p.
TERA. 1982. Proposed mitigation plan and environmental assessment, Hartz Mountain permit application, Public Notice 112255-82-391-J2. For submission to Army Engineer District, New York City. King of Prussia PA. 21 p. plus appendixes.
TERA. 1982. Supplement to proposed mitigation plan and environmental assessment, Hartz Mountain Permit Application 82-391. For submission to Army Engineer District, New York City. King of Prussia PA. 7 p.
TERA. 1982. Summary environmental assessment report concerning tidal wetlands proposed for development in North Bergen and Secaucus, Hackensack Meadowland District, Hudson County, New Jersey. King of Prussia PA. 25 p.
Schmid & Co. 1982. Environmental assessment of a proposed solid fill bridge for a private truck crossing, Delaware River tributary cove, Falls Township, Bucks County, Pennsylvania. Prepared on behalf of the Warner Company, Real Estate Division, for submission to Third Coast Guard District, Governors Island, New York City. Media PA. 40 p. plus appendixes.
Schmid & Co. 1982. Analysis of proposed mitigation for filling of wetlands, Hartz permit application, Public Notice 112255-82-391-J2. For submission to Army Engineer District, New York City. Media PA. 20 p.

Schmid & Co. 1983. Measures to offset unavoidable adverse impacts on wetlands from proposed development of a site in Barnegat Light, Ocean County, New Jersey. Prepared for S. T. Hudson Engineers, Inc., on behalf of Myers Clamming, Inc. Media PA. 2 p. plus drawings.
Schmid & Co. 1983. Metals in marsh sediments and implications for development of a site in North Bergen and Secaucus, New Jersey. Prepared for Hartz Mountain Development Corporation. Media PA. 20 p.
Schmid & Co. 1983. Statement of Dr. James A. Schmid regarding site conditions and potential impacts of development on the Oxly tract, Stafford Township, Ocean County, New Jersey. Prepared in defense of a hardship waiver granted by the New Jersey Pinelands Commission. Media PA. 16 p.

Schmid & Co. 1984. Wetlands on the site of the proposed Florham Park Corporate Centre, Borough of Florham Park, Morris County, New Jersey. Prepared for the Linpro Company, Morristown NJ. Media PA. 32 p.
Schmid & Co. 1984. Probable extent of lands not subject to Department of the Army jurisdiction under section 4O4 of the Clean Water Act on a site in the Borough of Florham Park, Morris County, New Jersey. Prepared on behalf of the Linpro Company for submission to Army Engineer District, New York City. Media PA. 36 p.
Schmid & Co. 1984. Identification of wetlands and wetland values on a site in the Borough of Florham Park, Morris County, New Jersey. Prepared for the Linpro Company for submission to the New Jersey Department of Environmental Protection. Media PA. 49 p.
Schmid & Co. 1984. Supplement to a report identifying wetlands on a site in the Borough of Florham Park, Morris County, New Jersey. Prepared for the Linpro Company. Media PA. 5 p.
Schmid & Co. 1984. Recommendations on the use of herbicides for the control of common reedgrass on a site in Secaucus and North Bergen, Hackensack Meadowland District, Hudson County, New Jersey. Prepared for Hartz Mountain Development Corporation. Media PA. 13 p.
Schmid & Co. 1984. Preliminary feasibility analysis of hybrid poplar sylviculture using municipal sludge on dredged spoil disposal areas, Logan Township, Gloucester County, New Jersey. Prepared for S. T. Hudson Engineers, Inc. Media PA. 10 p.
Schmid & Co. 1984. Existing conditions and potential wetland impacts on a site in the Township of Parsippany-Troy Hills, Morris County, New Jersey. Prepared on behalf of Crow-Foody Central, Pine Brook NJ, for submission to Army Engineer District, New York City. Media PA. 15 p.
Schmid & Co. 1984. Potential impacts on the proposed Hamilton Woods Adult Residential Development adjacent to wetlands on a site in Hamilton Township, Atlantic County, New Jersey. Prepared on behalf of P. and A. Greenberg, Cherry Hill NJ, for submission to the New Jersey Pinelands Commission. Media PA. 10 p.
Schmid & Co. 1984. Plan for mitigation to compensate for environmental values associated with proposed fill of an excavated barge slip, Petty Island, Camden County, New Jersey. Prepared for S. T. Hudson Engineers and Crowley/Trailer Marine Terminal. Media PA. 2 p.
Schmid & Co. 1984. Summary of environmental sensitivity of the southwestern section of Petty Island, Pennsauken Township, Camden County, New Jersey. Prepared for S. T. Hudson Engineers and Crowley/Trailer Marine Terminal. Media PA. 2 p.

Schmid & Co. 1985. Permit requirements and potential environmental impacts of a proposed marine bulk orange juice handling and storage terminal, Port Elizabeth, New Jersey. Prepared for Cargill Citro-America, Inc., Minneapolis MN. Media PA. 23 p.
Schmid & Co. 1985. Wetlands on the site of the proposed Greenlands project, South Brunswick Township, Middlesex County NJ. Prepared for Cavendish Development Co. for submission to Army Engineer District, New York City. Media PA. 20 p.
Schmid & Co. 1985. Wetlands on the site of the proposed Bromley project, Burlington Township NJ. Prepared for GSRA Associates for submission to Army Engineer District, Philadelphia PA. Media PA. 30 p.
Schmid & Co. 1985. Wetlands on the Pinson site, proposed Allen Road Development, Liberty Corner, Bernards Township, Somerset County NJ. Prepared for Paulus Sokowlowski & Sartor, Consulting Engineers, for submission to Army Engineer District, New York City. Media PA. 10 p.
Schmid & Co. 1985. Report on site conditions at a proposed warehouse development, Fairfield Township, Essex County, Passaic River Basin, New Jersey. Prepared on behalf of New Jersey Management Corporation, for submission to the Army Corps of Engineers. Media PA. 12 p.
Schmid & Co. 1985. Report on a field inspection of a site, East Rutherford, Bergen County, New Jersey. Prepared on behalf of Oakdale Hotels, Inc., for submission to the Army Corps of Engineers. Media PA. 11 p.

Schmid & Co. 1985. Wildlife habitat values on the Laurel Harbor proposed resubdivision project site, Lacey Township, Ocean County, New Jersey. Prepared on behalf of Charles H. Mackie Associates for submission to New Jersey Department of Environmental Protection (CAFRA Permit Application 85-0716-5). Media PA. 11 p.

Schmid & Co. 1985. Wetlands on the site of the proposed Quadrant 3 urban renewal site, Wayne Township, Passaic County, New Jersey. Prepared on behalf of Farcal Realty, Inc., for submission to the Army Corps of Engineers. Media PA. 22 p.

Schmid & Co. 1985. Wetlands, fill, and mitigation at the Summit Corporate Research Center, Edison Township, Middlesex County, New Jersey. Prepared on behalf of Summit Associates, Inc., for submission to Army Corps of Engineers. Media PA. 25 p.

Schmid & Co. 1985. Wetlands on an office building site, Borough of Roseland, Essex County, New Jersey. Prepared for Cali Associates for submission to the Army Corps of Engineers. Media PA. 13 p.

Schmid & Co. 1985. Wetlands adjacent to the Oradell Reservoir, Borough of Emerson, Bergen County, New Jersey. Prepared on behalf of the Hackensack Water Company for submission to the Army Corps of Engineers. Media PA. 14 p.

Schmid & Co. 1985. Wetlands on the Washington Greene project site, Washington Township, Mercer County, New Jersey. Prepared on behalf of Toll Brothers for submission to the Army Corps of Engineers. Media PA. 21 p.

Schmid & Co. 1985. Environmental conditions on a proposed residential project site, West Windsor Township, Mercer County, New Jersey. Prepared on behalf of Crow, Terwilliger & Dressler, Inc., for submission to the Army Corps of Engineers. Media PA. 17 p.

Schmid & Co. 1985. Environmental conditions on a 37-acre project site in Hillsborough Township, Somerset County, New Jersey. Prepared on behalf of the Garden State Lands Company for submission to the Corps of Engineers. Media PA. 14 p.

Schmid & Co. 1985. Wetlands on the East Harbour III study site, Morse Reservoir, Hamilton County, Indiana. Prepared on behalf of the Shorewood Corporation, for submission to the Army Corps of Engineers. Media PA. 23 p.

Schmid & Co. 1985. Wetlands on the site of the proposed Timber Ponds development, South Brunswick Township, Middlesex County, New Jersey. Prepared for Toll Brothers, Horsham PA. Media PA. 18 p.

Schmid & Co. 1985. Wetlands at a site along Omar Avenue, Woodbridge Township, Middlesex County, New Jersey. Prepared for Federal Business Centers, Inc., Edison, NJ. Media PA. 15 p.

Schmid & Co. 1985. Wetlands on the site of the proposed Forest Park Corporate Center, West Deptford Township, Gloucester County, New Jersey. Prepared for Trammell Crow Company, Philadelphia PA. Media PA. 17 p.

Schmid & Co. 1985. Wetlands on the NJHA - Bowers Associates site, Alexander Road, West Windsor Township, Mercer County, New Jersey. Prepared for Bowers Design Associates, Princeton NJ. Media PA. 17 p.

Schmid & Co. 1985. Wetlands on the 16 Roszel Road project site, West Windsor Township, Mercer County, New Jersey. Prepared for Bowers Design Associates, Princeton NJ. Media PA. 19 p.

Schmid & Co. 1985. Wetlands on a site along Little Bear Brook, West Windsor Township, Mercer County, New Jersey. Prepared for Waters McPherson McNeill and Jamieson, Moore, Peskin & Spicer. Media PA. 14 p.

Schmid & Co., Inc. 1985. Compliance with US Environmental Protection Agency guidelines for fill placement--Clean Water Act Section 404 (b)(1)--on an urban renewal site, Quadrant 3, Wayne Township, Passaic County, New Jersey. Prepared for Farcal Realty, Inc., for submission to Army Corps of Engineers. Media PA. 46 p.

Schmid & Co., Inc. 1986. Environmental impact statement on the construction and operation of the proposed Bromley at Burlington Phase I development, Burlington Township, Burlington County, New Jersey. Prepared for GSRA Associates and Bromley Enterprises for submission to Burlington Township. Media PA. 59 p.

Schmid & Co., Inc. 1986. Wetlands on the Pinebrook project site, Montville Township, Morris County, New Jersey. Prepared for Pine Valley Development Co. Media PA. 17 p.

Schmid & Co., Inc. 1986. Probable extent of wetlands at Atrium at Two Bridges site, Fairfield Township, Essex County, New Jersey. Prepared for Sprout Development Corporation. Media PA. 14 p.

Schmid & Co., Inc. 1986. Comments regarding the extent and implication of wetlands on a tract in Woodbridge Township, Middlesex County, New Jersey. Prepared for Waters McPherson McNeill and the Trust for Public Lands. Media PA. 13 p.

Schmid & Co., Inc. 1986. Preliminary environmental guidance concerning a tract in Tinton Falls Borough, Monmouth County, New Jersey. Prepared for Bottone Realty Group, Port Monmouth NJ. Media PA. 9 p.

Schmid & Co., Inc. 1986. Wetlands on the Lincoln Park Airport site, Borough of Lincoln Park, Morris County, New Jersey. Prepared for Lincoln Park Airport. Media PA. 23 p.

Schmid & Co., Inc. 1986. Extent of wetlands on the site of the proposed East Windsor Business Park, East Windsor Township, Mercer County, New Jersey. Prepared for Winitsky Associates, Abington PA. Media PA. 17 p.

Schmid & Co., Inc. 1987. Review of federal environmental assessment on proposed access ramps to Interstate 95, Ridgefield Park, Bergen County, New Jersey. Prepared for RKO Century Warner Theaters, Inc. Media PA. 14 p.

Schmid & Co., Inc. 1987. Compliance with US Environmental Protection Agency guidelines for fill placement at Raritan Center, Middlesex County, New Jersey, pursuant to the Clean Water Act. Section 404 (b)(1). Prepared for Summit Associates, Inc. Media PA. 20 p.

Schmid & Co., Inc. 1987. Environmental evaluation of the Penllyn Woods site, Lower Gwynedd Township, Montgomery County, Pennsylvania. Prepared for Lower Gwynedd Township Commissioners. Media PA. 34 p.

Schmid & Co., Inc. 1987. Draft analysis of ocean dune destruction project proposed by Normandy Shores Beach Association, Long Beach Island, Dover Township, Ocean County, New Jersey. Media PA. 8 p.

Schmid & Co., Inc. 1987. Compliance with EPA 404(b)(1) guidelines for placement of fill material at a proposed sanitary landfill, Shade Township, Somerset County, New Jersey. Prepared for Resource Conservation Corporation, Johnstown PA, for submission to Pittsburgh District, Army Corps of Engineers. Media PA. 135 p.

Schmid & Co., Inc. 1988. Federal wetland requirements and policies at Summit Corporate Research Center, Edison Township, Middlesex County, New Jersey. Prepared for Summit Associates, Inc. Media PA. 15 p.

Schmid & Co., Inc. 1988. The impacts of wastewater discharge permit violations on Delaware River water quality and biota at the AMSPEC Chemical Corporation plant, Gloucester City, Camden County, New Jersey, May 1984-October 1987. Prepared for Terris, Edgecombe, Hecker & Wayne, Washington DC. Media PA. 16 p.

Schmid & Co., Inc. 1988. Assessment of environmental impacts for a proposed PUD development on a site at Raritan Center. Prepared for Garden State Buildings, L.P., and Summit Associates, Inc. Media PA. 27 p.

Schmid & Co., Inc. 1988. Wetland inventory of the Chambers Works wastewater treatment plant, Upper Penns Neck Township, Salem County, New Jersey. Prepared for E.I. DuPont de Nemours & Co., Inc. Media PA. 50 p.

Schmid & Co., Inc. 1989. Oceanfront dune destruction, Normandy Shores Beach Association, Island Beach, Dover Township, Ocean County, New Jersey. Prepared for Harold V. Cano, M.D., and Elmer Johnson, Normandy Shores, New Jersey. Media, PA. 60 p.

Schmid & Co., Inc. 1989. Environmental review of the proposed River Birch Estates subdivision, Block 78, Lots 21.02, 21.03, and 22, Manalapan Township, Monmouth County NJ. For submission to New Jersey Department of Environmental Protection on behalf of Garden State Buildings, Edison NJ. Media PA. 20 p.

Schmid & Co., Inc. 1989. Environmental review of the Woodloch Springs site and assessment of proposed development, Lackawaxen Township, Pike County, Pennsylvania. Prepared for SMC Martin, Inc. and Woodloch Springs Resort for submission to the Pennsylvania Department of Environmental Resources. Media PA. 52 p.

Schmid & Co., Inc. 1990. Wetlands at 24 Paper Mill Road, Newtown Township, Delaware County, Pennsylvania. Prepared for Neighbors Organized to Stop Effluent to Darby Creek. Media PA. 29 p.

Schmid & Co., Inc. 1990. Wetland creation concept in mitigation for the proposed expansion of the Meadville Mall, Vernon Township, Crawford County, Pennsylvania. Prepared for George D. Zamias, Johnstown PA. Media PA. 14 p.

Schmid & Company, Inc. 1991. Conceptual plan for wetland creation, Lakeview Estates subdivision, Lehigh Township, Wayne County, Pennsylvania. Prepared for Lakeview Estates International Corporation, Valley Forge PA. Media PA. 6 p.

Schmid & Company, Inc. 1991. Wetland identification at the DuPont Chambers Works, Carneys Point and Pennsville Townships, Salem County, New Jersey. Prepared for E.I. DuPont de Nemours & Company, Inc., Deepwater NJ. Media PA. 74 p.

Schmid & Company, Inc. 1992. Review of proposed wetland boundary determinations at Penllyn Woods, Lower Gwynedd Township, Montgomery County, Pennsylvania, with recommendations for regulatory decisionmaking. Prepared on behalf of Supervisors of Lower Gwynedd Township. Media PA. 103 p.

Schmid & Company, Inc. 1992. Chambers Works secure landfill D final landscape/site plan for lands within 500 feet of the Delaware River, Carneys Point Twp., Salem Co., NJ. Prepared for E. I. DuPont de Nemours & Co., Inc. Media PA. 6 p.

Schmid & Company, Inc. 1992. Conceptual revegetation plan, Monroeville Landfill, Allegheny County, Pennsylvania. Prepared for Chambers Development Company. Media PA. 9 p.

Schmid & Company, Inc. 1992. Final monitoring report on wetland creation, wastewater treatment plant expansion, Chambers Works, Carneys Point Township, Salem County, New Jersey. Prepared for E. I. DuPont de Nemours & Co., Inc., Deepwater NJ. 44 p.

Schmid & Company, Inc. 1993. Summary report on functions and values of wetlands at the Meadville Mall, Vernon Township, Crawford County, Pennsylvania. Prepared for George D. Zamias, Developer. Media PA 4 p.

Schmid & Company, Inc. 1993. Conceptual plan for a proposed wetland mitigation bank in Salem County, New Jersey, for the DuPont Chambers Works. Prepared for the DuPont Chambers Works, Deepwater NJ. Media PA. 49 p.

Schmid & Company, Inc. 1993. Wetland primer for realtors. Prepared for Mark P. Klein, Polley Real Estate Education Co., Newtown Square PA. Media PA. 23 p.

Schmid & Company, Inc. 1993. Alternatives for restoration of intertidal shallows and marsh creation, Mallard View subdivision, Brick Township, Ocean County, New Jersey. Prepared for Yardville National Bank, Morrisville NJ. Media PA. 17 p.

Schmid & Company, Inc. 1994. Ecological assessment of a forested wetland swale at the American Nickeloid Company's Walnutport facility, Northampton County, Pennsylvania. Prepared for American Nickeloid Company, Peru IL. Media PA. 22 p.

Schmid & Company, Inc., and ACT Engineers, Inc. 1994. Statement of compliance with NJDEPE Coastal Resource and Development Rules for a Waterfront Development Permit application. Prepared for Yardville National Bank, Trenton NJ. Media PA. 8 p.

Schmid & Company, Inc. 1994. Wetlands, wetland destruction by a sanitary sewer project, and recommendations for wetland protection and impact mitigation in Lower Makefield Township, Bucks County, Pennsylvania. Prepared for D. and M. Bechis, Yardley PA. Media PA. 60 p.

Schmid & Company, Inc. 1994. Applicant's response to comments to Corps of Engineers Public Notice CENAP-OP-R-1994-00847, Mallard View Subdivision, Kettle Creek Lagoon, Brick Township, Ocean County, New Jersey. Prepared for the Yardville National Bank, Trenton NJ. Media PA. 18 p. plus attachments.

Schmid & Company, Inc. 1994. Wetland conditions and former uses at a site in Tinicum Township, Delaware County, Pennsylvania. Prepared for Harper Associates, Ridley Park PA. Media PA. 86 p.

Schmid & Company, Inc. 1995. Location and extent of apparent wetlands on the Loch Aerie project site, East Whiteland Township, Chester County, Pennsylvania. Prepared for Greenberg-Farrow Architecture, Inc., Atlanta GA. Media PA. 36 p.

Schmid & Company, Inc. 1995. Groundwater monitoring and wetland investigation, Block 544, Lot 233B, Hamilton Township, Mercer County, New Jersey. Prepared for Gallo, Stein, Celler & Burke, Trenton NJ. Media PA. 77 p.

Schmid & Company, Inc. 1995. Environmental conditions on the Greenwood Square Phase II site, Bensalem Township, Bucks County, Pennsylvania. Prepared for Greenwood Square Associates, Bensalem PA. Media PA. 46 p.

Schmid & Company, Inc. 1995. Wetland investigations at Arbor Meadow Farm, Horsham Townsip, Montgomery County PA. Prepared for Dr. Norman Werther. Media PA. 54 p.

Schmid & Company, Inc. 1995. Wetland mitigation plan, NJDEP Permit 0809-90-12.4-FWIP and USACE Permit CENAP-OP-R-199500016-15, Logan Township, Gloucester County, New Jersey. Prepared for Godwin Pumps of America, Inc. Media PA. 51 p.

Schmid & Company, Inc. 1995. Respondent's proposed restoration and enhancement, Consent Order EPA-CWA-II-87-78. Prepared for Garden State Buildings, L.P., and Summit Associates, Inc. Media PA. 4 sheets. Scale, 1:1,200.

Schmid & Company, Inc. 1996. Wetland investigation at the Paradise Pools site, Block 8, Lot, 8, West Windsor Township, Mercer County, New Jersey. Prepared for Paradise Pools, Inc., Mercerville NJ. 94 p.

Schmid & Company, Inc. 1996. Wetland mitigation plan for Estates Boulevard, Hamilton Township, Mercer County, New Jersey. Prepared for Township of Hamilton. Media PA. 51 p.
Schmid & Company, Inc. 1996. Joint permit application for Eagleton Farms Subdivision, Newtown Township, Bucks County, Pennsylvania. Prepared for Newtown Enterprises. Media PA. 81 p.
Schmid & Company, Inc. 1996. Joint permit application for Williamson Free School of Mechanical Trades, Middletown Township, Delaware County, Pennsylvania. Media PA. 103 p.

Schmid & Company, Inc. 1997. Environmental conditions at a site on Manhattan Street near Surf Avenue, Tottenville, Borough of Staten Island, Richmond County, New York. Prepared for Calvanico Associates, Inc. Media PA. 40 p.
Schmid & Company, Inc. 1997. Wetland conditions at the BGP II, Inc., tract, Middletown Township, Delaware County, Pennsylvania. Prepared for BGP II, Inc. Media PA. 50 p.
Schmid & Company, Inc. 1997. Update on planning prior to application for final approval of the Salem River Corridor wetland mitigation bank. Prepared for DuPont Chambers Works. Media PA. 12 p.
Schmid & Company, Inc. 1997. Wetland conditions at a site in Sayen Park, Hamilton Township, Mercer County, New Jersey. Prepared for Hamilton Township. Media PA. 46 p.

Schmid & Company, Inc. 1998. Prospectus for a Salem River corridor wetland mitigation bank, Salem County, New Jersey. Prepared for DuPont Chambers Works. Media PA. 31 p.
Schmid & Company, Inc. 1998. Review of state permits and likely environmental impacts for a proposed valley fill and coal preparation plant, North Bethlehem Township, Washington County, Pennsylvania. Prepared for the Raymond Proffitt Foundation. Media PA. 27 p.
Schmid & Company, Inc. 1998. Wetlands on a proposed bypass corridor north of New Jersey Route 33, Robbinsville, Mercer County, New Jersey. Prepared for the Township of Washington. Media PA. 33 p.
Schmid & Company, Inc. 1998. Wetlands on a proposed bypass corridor south of New Jersey Route 33, Robbinsville, Mercer County, New Jersey. Prepared for the Township of Washington. Media PA. 44 p.
Schmid & Company, Inc. 1998. Wetland investigation in the vicinity of proposed visitor center improvements, Grey Towers National Historic Landmark, Milford Township, Pike County, Pennsylvania. Prepared for Andropogon Associates and the United States Forest Service. Media PA. 29 p.
Schmid & Company, Inc. 1998. Environmental report to accompany stream encroachment permit application for Landfill C expansion, Cell 5A, Chambers Works, Carneys Point Township, Salem County, New Jersey. Prepared for E.I. DuPont de Nemours & Co., Inc., Deepwater NJ. Media PA. 13 p.

Schmid & Company, Inc. 1999. Potential impacts of a proposed quarry on streams and wetlands in the Hay Creek watershed, Birdsboro, Berks County, Pennsylvania. Prepared for the Borough of Birdsboro and the Birdsboro Municipal Authority. Media PA. 21 p.

Schmid & Company, Inc. 2000. Environmental inventory and assessment, proposed expansion of Landfill B, Chambers Works, Carneys Point Township, Salem County, New Jersey. Prepared for E.I. DuPont de Nemours & Co., Inc., Deepwater NJ. Media PA. 38 p.
Schmid & Company, Inc. 2000. Pennsylvania Chapter 105/Clean Water Act Section 404 joint permit application, Ridley Shopping Center Phase II, Ridley Township, Delaware County, Pennsylvania. Prepared for Harper Associates, Ridley Park PA. Media PA. Variously paged.
Schmid & Company, Inc. 2000. Wetlands and longwall mining, regulatory failure in southwestern Pennsylvania. Prepared for the Raymond Proffitt Foundation, Langhorne PA. Media PA. 123 p. http://www.schmidco.com/Wetlands%20and%20Longwall%20Mining%202000.pdf
Schmid & Company., Inc. 2000. Description of site conditions for a jurisdictional determination and plan to provide wetland mitigation for a property along East Ridley Avenue, Ridley Park Borough, Delaware County, Pennsylvania. Prepared for Harper Associates, Ridley Park PA. Media PA. 50 p.
Schmid & Company, Inc. 2000. Site conditions at a property along Middletown Road at Van Leer Avenue, Middletown Township, Delaware County, Pennsylvania. Prepared for S. Abboud, Wallingford PA. Media PA. 31 p.
Schmid & Company, Inc. 2000. Critique of special conditions wetland evaluation, Birdsboro Materials Quarrry, Robeson and Union Townships, Berks County, Pennsylvania. Prepared for Borough of Birdsboro and Birdsboro Municipal Authority. Media PA. 23 p.

Schmid & Company, Inc. 2003. Environmental conditions at a property along Aultman Avenue, Lot 5, Block 2262, Staten Island, Richmond County, New York. Prepared for Kling Real Estate, Ltd., Staten Island, New York. Media PA. 59 p.
Schmid & Company, Inc. 2003. Wetland resource value classification, Lot 15, Block 60, Borough of Bloomingdale, Passaic County, New Jersey. Prepared for P. Gasperini, San Francisco, California. Media PA. 22. p.
Schmid & Company, Inc. 2003. Site conditions at the Blue Heron Landing development, Swan Point, Cuckold Point Road, Baltimore County, Maryland. Prepared for Norman Anderson, Baltimore, Maryland. Media PA. 44 p.
Schmid & Company, Inc. 2003. Environmental report to accompany applications for stream encroachment permit and freshwater wetland general permit #11, Block 185, Lot 1, Carneys Point Township, Salem County, New Jersey. Prepared for E.I. DuPont de Nemours & Co. Chambers Works. Media PA. 43 p.

Schmid & Company, Inc. 2004. Environmental conditions and potential impacts from a proposed Henderson office campus on the Elwyn Tract along Ridley Creek, Middletown Township, Delaware County, Pennsylvania. Prepared for Chester-Ridley-Crum Creeks Watershed Association, Middletown Land Conservancy, and Upper Providence Open Space. Media PA. 34 p.
Schmid & Company, Inc. 2004. Response to agency comments regarding Cabela's Retail Center, Tilden Township, Berks County, Pennsylvania. Prepared for Cabela's Inc., Sydney, Nebraska. Media PA. 99 p.

Schmid & Company, Inc. 2005. Site conditions at the Dia Center site, City of Beacon, Dutchess County, New York. Prepared for Dia Center for the Arts, Inc. Media PA. 44 p.
Schmid & Company, Inc. 2005. Compensatory mitigation plan for the Kernsville Desilting Basin site. Prepared for Cabela's Retail Center, Tilden Township, Berks County PA. Media PA. 18 p.

Schmid & Company, Inc. 2007. Wetlands and wetland incursions at Hopewell Nursery Farm 3, Cumberland County, New Jersey. Prepared for RT Environmental Services, Inc. Media PA. 104 p.

Schmid & Company, Inc. 2007. An investigation of existing and historic environmental conditions at Arlington Cemetery associated with alleged NJDEP violations and a proposed resolution, Lots 2 and 3, Block 134, Town of Kearny, Hudson County, New Jersey. Prepared for Arlington Cemetery Association. Media PA. 106 p.

Schmid & Company, Inc. 2008. Unnecessary and unacceptable impacts of the proposed Sentinel Ridge development, Marple Township, Delaware County, Pennsylvania; an expert opinion. Prepared for Crum Creek Neighbors, Appellants. Pennsylvania Environmental Hearing Board Docket No. 2007-287-L. Media PA. 95 p.

Schmid & Company, Inc. 2009. Alleged activities in wetlands and transition areas at Lot 1, Block 1301, Upper Deerfield Township, Cumberland County, New Jersey. Prepared for Neil Yoskin, Esq., Princeton NJ. Media PA. 28 p.

Schmid & Co., Inc. 2009. Our water quality: Streams and stream protection in the 7th Congressional District of Pennsylvania. Media PA. 8 pages plus poster. www.schmidco.com

Schmid & Company, Inc. 2009. Comments on NPDES Permit Application PA 1023909008, Stubits proposed land development (day-care center), Lot 4B, Block 19, E5, Heidelberg Township, Lehigh County, Pennsylvania. Prepared for D. W. Miles, Esq., and Sierra Club of Pennsylvania. Media PA. 7 p.

Schmid & Company, Inc. 2009. Protecting our streams in Wallace Township, Chester County PA. Prepared for Guardians of the Brandywine, Inc. Poster. http://www.watchourwaters.org/water_resources.htm

Schmid & Company, Inc. 2009. Supplemental report on alleged filling of wetlands at Lot 1, Block 1301, Upper Deerfield Township, Cumberland County, New Jersey. Media PA. 42 p.

Schmid & Company, Inc. 2010. Expert opinion regarding wetlands and wetland incursions at Hopewell Nurseries Farm 3, Deerfield Township, Cumberland County, New Jersey. Prepared for Hopewell Nursery, Bridgeton NJ. Media PA. 124 p.

Schmid & Company, Inc. 2010. Protection of water resources from longwall mining is needed in southwestern Pennsylvania. Prepared for Citizens Coal Council, Washington PA, with support from The Sierra Club. Media PA. 190 p. http://www.schmidco.com/Final%20Report%2026%20July%202010.pdf

Schmid & Company, Inc. 2010. Proposed Fredericksville Farms, Berks County, Pennsylvania. Prepared for John Wilmer, Esq. Media PA. 28 p.

Schmid & Company, Inc. 2011. Streams and wetlands on Bear Mountain, Elkland Township, Sullivan County, Pennsylvania. Prepared for Bear Mountain Homeowners. Media PA. 74 p.

Schmid & Company, Inc. 2011. Proposed sewage discharges and wetland impacts at the Fredericksville Farms Subdivision, District and Longswamp Townships, Berks County, Pennsylvania. Prepared for: John Wilmer, Esq. Media PA. 15 p.

Schmid & Company, Inc. 2011. Review of proposed wetland modeling and probable wetland damage, Fredericksville Farms Subdivision, District and Longswamp Townships, Berks County, Pennsylvania. Prepared for John Wilmer, Esq. Media PA 31 p.

Schmid & Company, Inc. 2011. Comments on proposed natural gas development regulations for the Delaware River basin. Presented to the Delaware River Basin Commission. Media PA. 18 p.

Schmid & Company, Inc. 2012. Delineated wetlands and streams in the eastern meadows at Longwood Gardens, Kennett, Pennsbury, and East Marlborough Townships, Chester County, Pennsylvania. Prepared for Bancroft Construction Company and Longwood Gardens. Media PA. 46 p.

Schmid & Company, Inc. 2012. Pilot contract for an independent technical review of the proposed Donegal Mine, Donegal Township, Butler County, Pennsylvania. Prepared for Pennsylvania Department of Environmental Protection on behalf of Rosebud Mining Company. Media PA 130 p.

Schmid & Company, Inc. 2012. Recommendations to expedite the Department's underground bituminous coal mine permit application reviews. Submitted to PADEP Office of Active and Abandoned Mine Operations, Harrisburg PA. Media PA. 17 p.

Schmid & Co., Inc. 2013. Natural resource concerns during proposed development at the Woodlawn Tract, Concord Township, Delaware County PA. Prepared for the Beaver Valley Conservancy, Concordville PA. Media PA. 62 p.

Schmid & Co., Inc. 2013. Streams and wetlands on the College Arms apartments property, 74 East Fifth Avenue, Collegeville Borough, Montgomery County PA. Prepared for TriRealty Company and Reed-Smith LLC. Media PA. 75 p. plus attachments.

Schmid & Co., Inc. 2014. The effects of converting forest or scrub wetlands to herbaceous wetlands in Pennsylvania. Prepared for the Delaware Riverkeeper Network, Bristol PA. Media PA. 48 p.

Schmid & Co., Inc. 2014. Analysis of impacts on wetlands and buffers, proposed Williams Transco Leidy Southeast Franklin Loop D Pipeline, Monroe and Luzerne Counties, Pennsylvania. Prepared for Delaware Riverkeeper Network, Bristol PA. Media PA. 49 p.

Schmid & Co., Inc. 2014. Supplement to streams and wetlands at the College Arms Apartments property. Prepared for TriRealty Company. Media PA. 23 p.

Schmid & Company, Inc. 2014. PADEP Regulatory Jurisdiction at Green Pond/Traditions of America Site, Bethlehem Township, Northampton County, PA. Prepared for savegreenpond.org. Media PA. 64 p.

Schmid & Co., Inc.. 2015. Natural resource concerns during development at the Woodlawn Tract, Concord Township, Delaware County, Pennsylvania. Prepared on behalf of the Beaver Valley Conservancy and Eileen Mutschler for submission to the Board of Supervisors, Concord Township. Media PA. 74 p.

Schmid & Co., Inc., and Patrick J. Fasano. 2015. Forest conditions at the site of the proposed Vineyard Commons Subdivision, Concord Township, Delaware County, Pennsylvania. Prepared for the Beaver Valley Conservancy and Eileen Mutschler. Media PA. 66 p.

Schmid & Co., Inc. 2015. Potential impacts on streams and wetlands from a proposed residential subdivision, Fredericksville Farms, District and Longswamp Townships, Berks County, Pennsylvania. Prepared for John Wilmer, Esquire, and the Pine Creek Valley Watershed Association. Media PA. 77 p.

Schmid & Co., Inc. 2015. Further comments on streams and wetlands from a proposed residential subdivision, Fredericksville Farms, District and Longswamp Townships, Berks County, Pennsylvania, in response to an expert report by Thomas Starosta PE dated 13 November 2015. Prepared for John Wilmer, Esquire, and the Pine Creek Valley Watershed Association. Media PA. 43p.

Schmid & Co., Inc. 2016. Regulated waters on the property of Tri Realty Company and within Bum Hollow, Collegeville Borough, Montgomery County, Pennsylvania. Prepared for Tri Realty Company. Media PA. 64 p.

Schmid & Co., Inc. 2018. Expert report on wetlands and streams at a property in Union Township, Huntingdon County, Pennsylvania. Prepared for Richard Raiders, Esq. Media PA. 30 p

Schmid & Co., Inc. 2018. Comments on proposed regulations of the Delaware River Basin Commission concerning high volume fracturing to produce oil and gas. Prepared for Delaware Riverkeeper Network. Media PA. 19 p.

- **Substantial Input**

JMA. 1973. Environmental impact statement on the construction and operation of Ocean Harbor, a residential and commercial development in the City of Brigantine, Atlantic County, New Jersey. Prepared for Brigantine Harbour, Inc., for submission to the New Jersey Department of Environmental Protection. Devon PA. 206 p.

JMA. 1975. The existing water quality of Lake Valhalla, Morris County, New Jersey, and an assessment of potential impacts on water quality of development in the watershed. Prepared for the Committee for the Preservation of Northern Montville. Devon PA. 22 p.

JMA. 1975. Natural resource inventory of the Middle Run study area, New Castle County, Delaware. Prepared for the New Castle County Department of Parks and Recreation. Devon PA. 129 plus 32 p.

JMA. 1975. Environmental assessment for the feasibility study for the land reclamation project, complementary urban development, City of Corinto, Nicaragua. Prepared for submission to the Autoridad Portuaria de Corinto and US-AID by Boswell-Amman & Whitney-Lamsa, Ingenieros Consultores. Devon PA. 116 p. plus folio maps.

JMA. 1975. Waterfowl in the Meadowlands Freeway (US Routes 1 & 9) study area, Hackensack Meadowlands District, Hudson and Bergen Counties, New Jersey. Submitted to the New Jersey Department of Transportation by Louis Berger & Associates, Inc. Berwyn PA. 25 p.

JMA. 1975. Inventory reports for Legislative Route 202 project area, Chester County, Pennsylvania. Prepared on behalf of Pennsylvania Department of Transportation, District 6-0. Berwyn PA. Variously paged, 377 p.

JMA. 1975. Request for the determination of eligibility for listing on the National Register of Historic Places of six historic sites in the corridor for the proposed improvements to Legislative Route 202, Charlestown Township and Schuylkill Township, Pennsylvania. Submitted to the Pennsylvania Historic and Museum Commission by the Pennsylvania Department of Transportation, District 6-0. Berwyn PA. 63 p.

JMA. 1976. Draft environmental impact statement, L.R. 202 (Phoenixville Pike), Pennsylvania Turnpike to City Line Avenue, Borough of Phoenixville, Chester County, Pennsylvania. Prepared for the Pennsylvania Department of Transportation, District 6-O, and the Federal Highway Administration. Berwyn PA. 170 p.

JMA. 1976. Application for the construction and operation of a residential development in Ocean County, Cape May County, New Jersey. Prepared on behalf of EVED Enterprises, Inc. for submission to the New Jersey Department of Environmental Protection. Berwyn PA. 26 p.

JMA. 1976. An assessment of beach erosion, with recommendations for the Borough of Ocean City, Cape May County, New Jersey. Berwyn PA. 102 p.

JMA. 1976. Archaeological investigations of a cartway and various structures at the Peter Wentz Farmstead, a National Register site, Shulz Road, Worcester Township, Montgomery County, Pennsylvania. Prepared for the Historical Advisory Board, Commissioners of Montgomery County. Berwyn PA. 37 p. plus map folio.

JMA. 1976. Quick response environmental impact assessment of dredging and filling at Harmon Cove, Specially Planned Area I, Secaucus, New Jersey. Submitted to the State of New Jersey, Hackensack Meadowlands Development Commission, by Hartz Mountain Industries, Inc. Berwyn PA. 10 p.

JMA. 1976. A report on the water quality and aquatic macroinvertebrates of Lake Saginaw, Sparta Township, Sussex County, New Jersey. Prepared for the Liberty Mutual Insurance Co., East Orange NJ. Berwyn PA. 25 p.

JMA. 1977. Evaluation of the potential effects of the Penn Estates development on the Tannersville Bog, Monroe County, Pennsylvania. Prepared for The Nature Conservancy, Boston MA. Berwyn PA. 65 p.

JMA. 1977. Final report on a document review and an archaeological reconnaissance of the William Floyd Estate and the Fire Island Lighthouse Tract, Suffolk County, New York, 1976. Submitted to Denver Service Center, National Park Service. Berwyn PA. 208 p.

JMA. 1977. Report on the feasibility of providing a housing program for low and moderate income residents of Lower Merion Township, Pennsylvania. Prepared on behalf of the Board of Commissioners, Lower Merion Township, Montgomery County PA. Berwyn PA. 100 p.

JMA. 1977. Environmental impact assessment of producing fast land at Harmon Cove in the Hackensack River, Secaucus, New Jersey. Prepared for Hartz Mountain Industries, Inc., Secaucus NJ. Berwyn PA. 41 p.

JMA. 1977. Short-term analysis of police services in the Town of Secaucus, New Jersey, and of police service requirements for the proposed Harmon Cove development. Prepared for Hartz Mountain Industries, Inc. Secaucus NJ. Berwyn PA. 5 p.

JMA. 1977. Revised analysis of municipal cost-review balance of proposed Harmon Cove development, Secaucus, New Jersey. Prepared for Hartz Mountain Industries, Inc., Secaucus NJ. Berwyn PA. 21 p.

JMA. 1977. Preliminary draft report on chemical pollutants of the New York Bight which should receive priority research attention. Prepared by a panel of invited experts for the Marine EcoSystems Analysis Project, National Oceanic and Atmospheric Administration, Stony Brook NY. Berwyn PA. 282 p.

JMA. 1978. Draft environmental impact statement for the proposed Lower Armstrong Power Station, Armstrong County, Pennsylvania. Prepared for the US Environmental Protection Agency, Region III, Philadelphia PA. Berwyn PA. 197 p.
JMA. 1978. Working draft environmental impact statement on the Horsham, Warminster, Warrington, Pennsylvania, 201 wastewater facilities construction grant applications. Prepared for US Environmental Protection Agency, Region III, Philadelphia PA. Berwyn PA. 502 p.
JMA. 1978. Cultural resource overview of the Olympic National Forest, Washington. Prepared for USDA Forest Service, Olympia WA. Berwyn PA. Volume 1. 213 p.

O'Connor, Joel S., and H. M. Stanford (eds.) 1979. Chemical pollutants of the New York Bight: priorities for research. Environmental Research Laboratories, US Department of Commerce, National Oceanic and Atmospheric Administration. Boulder CO. 217 p.
WAPORA. 1979. Draft environmental impact statement, administrative action: disposal of surplus Federal real property of the Frankford Arsenal, Philadelphia, Pennsylvania. Prepared for the General Services Administration in association with Harland Bartholomew & Associates, Inc. Berwyn PA. 230 p.
WAPORA. 1979. Stormwater quality evaluation from the proposed parking garage at Harmon Cove IV, V, and VI. Prepared for Hartz Mountain Industries, Inc., Secaucus NJ. Berwyn PA. 20 p.
WAPORA. 1979. Environmental factors affecting surface mining of steeply pitching and coal seams. Prepared for Ketron, Inc., Wayne PA, for US Bureau of Mines. Berwyn PA. 134 p.

WAPORA. 1980. Cultural resources survey of six areas proposed for land exchanges and timber sales within the Olympic National Forest, Washington. Prepared for USDA Forest Service, Olympia WA. Berwyn PA. 289 p.
WAPORA. 1980. Draft task report on the development of NEPA compliance strategies for the Eastern Kentucky coalfield (New Source NPDES permit program). Prepared for US Environmental Protection Agency, Region IV, Atlanta GA. Berwyn PA. 151 p.
WAPORA. 1980. Report of a comprehensive archaeological reconnaissance and National Register eligibility tests at the Terror Lake hydroelectric project site, Kodiak Island, Alaska, 1980. Prepared for International Engineering Company, San Francisco CA. Berwyn PA. Variously paged, 183 p.
USEPA Region III. 1980. Coal/Kanawha River Basin supplemental information document, areawide environmental assessment for issuing New Source NPDES permits for coal mines. Philadelphia PA. Variously paged, 992 p.

WAPORA. 1981. An inventory of environmental resources and an analysis of potential impacts of proposed development on backbarrier tidal marsh along the central Delaware Bay coast at Slaughter Beach, Sussex County, Delaware. Prepared for Delaware Department of Natural Resources and Environmental Control, Dover DE. Berwyn PA. 79 p.
USEPA Region III. 1981. Environmental impact assessment and finding of no significant impact on new source coal mining in West Virginia. Philadelphia PA. 61 p.
TERA. 1981. Supplemental draft environmental impact statement, Finance Docket No. 29254, Somerset Railroad Corporation, construction and operation of a line of railroad in Niagara County, New York. Prepared for Interstate Commerce Commission. King of Prussia PA. 454 p. plus map atlas.

TERA. 1982. Stream encroachment permit application for Collings Avenue cargo yards, Newton Creek, Gloucester NJ, for submission to Bureau of Floodplain Management, NJ Department of Environmental Protection. King of Prussia PA, 25 p.
TERA. 1982. Stream encroachment application for marginal wharf, Delaware River, Gloucester, NJ, for submission to Bureau of Floodplain Management, NJ Department of Environmental Protection. King of Prussia PA. 50 p.
TERA. 1982. Draft environmental impact statement on Churchill Town Sector, Germantown, Montgomery County, Maryland. Prepared for the US Department of Housing and Urban Development, Region III. King of Prussia PA. 195 p.

Schmid & Co. 1983. Final environmental impact statement on Churchill Town Sector, Germantown, Montgomery County, Maryland. Prepared for US Department of Housing and Urban Development, Region III. Media PA. 57 p.
Schmid & Co. 1983. Specifications for wetland reclamation and mitigation site work, Camden County Park site, Camden County, New Jersey. For submission to Army Engineer District, Philadelphia PA and New Jersey Division of Coastal Resources. Media PA. 51 p.
Schmid & Co. 1983. Water balance analysis and implications for pond management, West Side Avenue Impoundment No. 1, North Bergen, New Jersey. Prepared for Hartz Mountain Development Corporation. Media PA. 9 p.

Meredith/Boli & Associates, Inc., and Schmid & Co. 1984. Review of state-level electric power transmission line siting programs. Prepared for Edison Electric Institute, Washington DC. Beverly Hills CA. 77 p.
Schmid & Co. 1984. Input to environmental assessment, Lewisburg Bridge reconstruction, Lewisburg, Pennsylvania, Susquehanna River. For submission to Pennsylvania Department of Transportation by Ketron, Inc., Wayne PA. Media PA. 29 p.

Schmid & Co., Inc. 1985. Shoreline enhancement study, vegetation and non-structural methods, Baltimore County, Maryland. Prepared for Rogers, Golden & Halpern and Baltimore County Office of Planning and Zoning. Media PA. 49 p.

Schmid & Co., Inc. 1986. Wetland mitigation plan for the proposed Steward's Watch project, West Windsor Township, Mercer County, New Jersey. Prepared for Crow, Terwilliger & Dressler, Inc. Media PA. 13 p.
Schmid & Co., Inc. 1986. Inventory of environmental resources on the site of the proposed sanitary landfill, Shade Township, Somerset County, Pennsylvania. Prepared for Resource Conservation Corporation, Johnstown PA. Media PA. 65 p.
Schmid & Co., Inc. 1986. Floodplains and wetlands on the Baldwin Locomotive site, Eddystone Borough, Ridley Park Borough, and Ridley Township, Delaware County, Pennsylvania. Prepared for the Henderson Group, Sharon Hill PA. Media PA. 30 p.

Schmid & Co., Inc. 1987. Raritan Center environmental inventory. Prepared for Summit Associates, Inc. and Federal Business Centers. Media PA. 2 vols. (335 + 232 p.)

Schmid & Co., Inc. 1987. Wetlands on the Lake Watawga study area, Wayne and Monroe Counties, Pennsylvania. Prepared for Lakeview Estates Corporation, Valley Forge PA. Media PA. 32 p.

Schmid & Co., Inc. 1987. Environmental inventory of the J. T. Mine study area proposed for compensation wetlands, Shade Township, Somerset County, Pennsylvania. Prepared for Resource Conservation Corporation, Johnstown PA. Media PA. 30 p.

Schmid & Co., Inc. 1987. Environmental inventory of the Willie Will Mine study area proposed for compensation wetlands, Shade Township, Somerset County, Pennsylvania. Prepared for Resource Conservation Corporation, Johnstown PA. Media PA. 31 p.

Schmid & Co., Inc. 1987. Environmental inventory of the Westbrooke residential project site, West Windsor Township, Mercer County, New Jersey. Prepared for Garden State Lands Group, Cranbury NJ. Media PA 29 p.

Schmid & Co., Inc. 1988. Wetlands on the Shadow Oaks project site, West Windsor Township, Mercer County, New Jersey. Prepared for Garden State Land Group, Cranbury NJ. Media PA. 25 p.

Schmid & Co., Inc. 1988. Wetland evaluation of the Shadow Oaks at Cranbury site, Block 21, Lot 8, Cranbury Township, Middlesex County, New Jersey. Prepared for Garden State Land Group, Cranbury NJ. Media PA. 31 p.

Schmid & Co., Inc. 1988. Wetland evaluation of the Cushetunk Lake site, Readington Township, Hunterdon County, New Jersey. Prepared for Trammell Crow Company, Princeton NJ. Media PA. 35 p.

Schmid & Co., Inc. 1989. Wetland identification at the Meadville Mall site, Vernon Township, Crawford County, Pennsylvania. Prepared for George D. Zamias, Johnstown, Pennsylvania. Media PA. 35 p.

Schmid & Co., Inc. 1989. Mitigation plan for the Wastewater Treatment Plant expansion at Chambers Works, Deepwater, New Jersey. Prepared for E.I. DuPont de Nemours & Co., Inc., Chambers Works, Deepwater NJ. Media PA. 20 p.

Schmid & Co., Inc. 1989. Wetland identification at the Bi-County development site, Oakland Borough (Bergen County) and Wayne Township (Passaic County), New Jersey. Prepared for Bi-County Development Corporation, Brooklyn NY. Media PA. 31 p.

Schmid & Co., Inc. 1989. Wetland identification at the Altman/Young Tracts, East Caln and Uwchlan Townships, Chester County, Pennsylvania. Prepared for T.H. Cahill & Associates, West Chester PA. Media PA. 39 p.

Schmid & Co., Inc. 1989. Wetland creation plan for mitigation of fill at wastewater treatment plant expansion, DuPont Chambers Works, Carneys Point Township, Salem County NJ. Prepared for submission to Philadelphia District, Army Corps of Engineers, by E. I. DuPont de Nemours & Co., Inc. Deepwater NJ. Media PA. 25 p.

Schmid & Co., Inc. 1990. Environmental impact statement, Weatherstone proposed residential development, Lots 14 and 145, Section 21, West Windsor Township, Mercer County, New Jersey. Prepared for Garden State Land Group, Cranbury NJ. Media PA. 17 p. plus appendix.

Schmid & Co., Inc. 1990. Wetland identification at the Hellertown site, City of Bethlehem, Northampton County, Pennsylvania. Prepared for Environmental Strategies Corporation, Vienna VA. Media PA. 28 p.

Schmid & Co., Inc. 1990. Wetland evaluation for Due Process Stable, Colts Neck Township and Tinton Falls Borough, Monmouth County, New Jersey. Media PA. 48 p.

Schmid & Co., Inc. 1990. Wetland identification at the Godwin Pumps site, Block 33, Lot 8.02, Logan Township, Gloucester County NJ. Prepared for Godwin Pumps of America. 20 p.

Schmid & Co., Inc. 1990. Wetland identification at the DuPont Chambers Works, Carneys Point and Pennsville Townships, Salem County, New Jersey. (Draft) Prepared for E. I. DuPont de Nemours & Co., Inc., Deepwater NJ, for submission to the New Jersey Division of Coastal Resources. Media PA. 74 p.

Schmid & Co., Inc. 1990. Wetland identification at the Floodgate Road site, Logan Township, Gloucester County, New Jersey. Prepared for American Dredging Co., Camden NJ. Media PA. 34 p.

Schmid & Co., Inc. 1990. Phase I environmental site assessment for Lots 14 and 145, Section 21 (Cranbury Golf Course), West Windsor Township, Mercer County, New Jersey. Prepared for Garden State Land Group, Cranbury NJ. Media PA. 28 p.

Schmid & Co., Inc. 1990. Wetland investigation for the Bender Road easement at the Lakeview Estates subdivision, Lehigh Township, Wayne County, Pennsylvania. Prepared for Lakeview Estates International Corporation, Valley Forge PA. Media PA. 61 p.

Schmid & Co., Inc. 1990. Wetlands at Block 195, Lots 6, 7, and 8, Brick Township, Ocean County, New Jersey, and regulatory implications. Prepared for the Trust for Public Lands, New York NY. Media PA. 29 p.

Schmid & Co., Inc. 1991. Wetland identification, Wings Field tract, Whitpain Township, Montgomery County, Pennsylvania. Prepared for LHC Realty/Wings Field Associates. Plymouth Meeting PA. Media PA 40 p.

Schmid & Co., Inc. 1991. Wetland investigations at Block 1DD, Lots 2-4, and Block 1BB, Lots 26-30, Pine Hill Borough, Camden County, New Jersey. Prepared for Richard B. Heller, Newtown Square PA. Media PA. 17 p.

Schmid & Co., Inc. 1991. Wetlands at Block 109, Lots 28, 29, and 31, Brick Township, Ocean County, New Jersey, and regulatory implications. Prepared for the Trust for Public Lands, New York NY. Media PA. 9 p.

Schmid & Co., Inc. 1991. Wetland investigation at the Suttmeier Tract, West Windsor Township, Mercer County, New Jersey. Prepared for Garden State Land Group. Media PA. 38 p.

Schmid & Co., Inc. 1991. Wetland investigation at Labato clay pit, Block 13, Lot 7, Alloway Township, Salem County, New Jersey. Prepared for Chambers Works, E. I. DuPont de Nemours & Co., Inc. Media PA. 36 p.

Schmid & Co., Inc. 1992. Phase I environmental audit and assessment, Shore Oaks Golf Club, Howell Township, Monmouth County, New Jersey. Prepared for Cannon Golf Enterprises, Inc., and McCarter & English, Newark NJ. 35 p.

Schmid & Co., Inc. 1993. Wetland conditions at the Gulph Road Bridge over Crow Creek, Upper Merion Township, Montgomery County, Pennsylvania. Prepared for Raymond Keyes Associates, Tarrytown NY. Media PA. 23 p.

Schmid & Co., Inc. 1994. Wetland conditions at the Woodside Road site, Washington Township, Mercer County, New Jersey. Prepared for Cenlar Federal Savings Bank, Princeton NJ. Media PA. 47 p.

Schmid & Co., Inc. 1994. Wetland identification, Envirotest Buck 2 facility site, Plumstead Township, Bucks County, Pennsylvania. Prepared for Envirotest Partners, Bala Cynwyd PA. 24 p.

Schmid & Co., Inc. 1994. Wetland conditions at the Envirotest Buck 5 inspection facility site, Falls Township, Bucks County, Pennsylvania. Prepared for Envirotest Partners, Bala Cynwyd PA. 31 p.

Schmid & Co., Inc. 1995. Wetland conditions on Lots 6, 12, and 233-A, Block 544, Hamilton Township, Mercer County, New Jersey. Media PA. 48 p.

Schmid & Co., Inc. 1995. Vegetation and wildlife inventory, Estates Boulevard project site, Hamilton Township, Mercer County, New Jersey. Prepared for Township of Hamilton. Media PA. 13 p.

Schmid & Co., Inc. 1995. Application to NJDEP for a regulatory line verification, Lot 10.03, Block 9, Kingwood Township, Hunterdon County, New Jersey. Prepared for Cenlar Federal Savings Bank. Media PA.

Schmid & Co., Inc. 1995. Wetland conditions at Morrows Marina, Ridley Township, Delaware County, New Jersey. Prepared for Driftwood Marina, Inc. Media PA. 31 p.

Schmid & Co., Inc. 1995. Wetland conditions at a site along Morton Avenue and MacDade Boulevard, Ridley Township, Delaware County, Pennsylvania. Prepared for Harper Associates, Ridley Park PA. Media PA. 44 p.

Schmid & Co., Inc. 1995. Wetland conditions at a site along George Dye Road and Klockner Road, Hamilton Township, Mercer County, New Jersey. Prepared for Stanley Neuman. Media PA. 72 p.

Schmid & Co., Inc. 1995. Wetland conditions at a site along Stouts Lane, South Brunswick Township, Middlesex County, New Jersey. Prepared for S. N. Golden Estates, Inc. Hamilton Square NJ. 36 p.

Schmid & Co., Inc. 1995. Wetland conditions at the Summit Avenue site, Norwood Borough, Delaware County, Pennsylvania. Prepared for T & E Contractors, Inc. Springfield PA. Media PA. 33 p.

Schmid & Company, Inc. 1995. Wetland conditions at a site along Cardiff Lane, Hamilton Township, Mercer County, New Jersey. Prepared for Mercer Capital Management, Inc., L.P. Hamilton, New Jersey. Media PA. 35 p.

Schmid & Co., Inc. 1995. Wetland conditions at the Harrison Tract, Newtown Township, Delaware County, Pennsylvania. Prepared for Durkin Associates, Inc., Erdenheim, Pennsylvania. Media PA. 42 p.

Schmid & Co., Inc. 1995. Wetland conditions at a site along Whitehorse-Hamilton Square Road, Block 542, Lot 8.02, Hamilton Township, Mercer County, New Jersey. Prepared for Kol-Tov Associates, Hamilton Square, New Jersey. Media PA. 43 p.

Schmid & Co., Inc. 1995. Application for Statewide General Permit, West Windsor Township, Mercer County, New Jersey. Prepared for Mercer Capital Management. Media PA.

Schmid & Co., Inc. 1996. Application for Transition Area Waiver, Lot 26, Block 535, Hamilton Township, Mercer County, New Jersey. Prepared for Estates Boulevard Company. Media PA. 25 p.

Schmid & Co., Inc. 1996. Wetland conditions at Wings Field, Whitpain Township, Montgomery County, Pennsylvania. Prepared for Wings Field Associates. Media PA. 58 p.

Schmid & Co., Inc. 1997. Wetland investigation: The Hamptons at Wayside, Ocean Township, Monmouth County, New Jersey. Prepared for Ocean 110, L.L.C. Media PA. 34 p.

Schmid & Co., Inc. 1997. Wetland conditions at Lot 4.003, Section 540.02, Hamilton Township, Mercer County, New Jersey. Prepared for TPM Partnership. Media PA. 52 p.

Schmid & Co., Inc. 1997. Wetland conditions at a site between Kuser Road and Interstate 195, Hamilton Township, Mercer County, New Jersey. Prepared for John T. Gervasoni. Media PA. 49 p.

Schmid & Co., Inc. 1997. Wetland conditions at the Yardville National Bank site, Section 96, Lot 359, Hamilton Township, Mercer County, New Jersey. Prepared for Yardville National Bank. Media PA. 39 p.

Schmid & Co., Inc. 1997. Wetland conditions at the Oak Meadow Lane site, Easttown Township, Chester County, Pennsylvania. Prepared for Durkin Associates, Inc. Media PA. 32 p.

Schmid & Co., Inc. 1997. Wetland conditions at Culligan Water Conditioning site, Sunfield Avenue, Raritan Center, Edison Township, Middlesex County, New Jersey. Prepared for Culligan Water Conditioning, Inc. Media PA. 30 p.

Schmid & Co., Inc. 1997. Wetland conditions at a property along Barclay and Brunswick Avenues, City of Margate, Atlantic County, New Jersey. Prepared for A. Silverstein. Media PA. 33 p.

Schmid & Co., Inc. 1997. Wetland conditions at a site along Patterson Avenue, Hamilton Township, Mercer County, New Jersey. Prepared for W. Matisa. Media PA. 31 p.

Schmid & Co., Inc. 1997. Preliminary site assessment for a site along Hobson and Emeline Avenues, Hamilton Township, Mercer County, New Jersey. Prepared for Hamilton Township Division of Planning. Media PA. 62 p.

Schmid & Co., Inc. 1997. Preliminary site assessment for a site along Kuser Road, Hamilton Township, Mercer County, New Jersey. Prepared for Hamilton Township Division of Planning. Media PA. 55 p.

Schmid & Co., Inc. 1997. Preliminary site assessment for a site along Paxson Avenue, Hamilton Township, Mercer County, New Jersey. Prepared for Hamilton Township Division of Planning. Media PA. 51 p.

Schmid & Co., Inc. 1997. Wetland conditions at a site along Melrich Road, South Brunswick Township, Middlesex County, New Jersey. Prepared for Summit/Greene Associates. Media PA. 40 p.

Schmid & Co., Inc. 1998. Wetland conditions at a site along Yardville-Hamilton Square Road, Hamilton Township, Mercer County, New Jersey. Prepared for Sharbell Development Corporation. Media PA. 36 p.

Schmid & Co., Inc. 1998. Wetland redelineation for the Ganes Chemicals property, Pennsville Township, Salem County, New Jersey. Prepared for Ganes Chemicals, Inc. Media PA. 59 p.

Schmid & Co., Inc. 1998. Wetland resource value classification at the Ganes Chemicals property, Pennsville Township, Salem County, New Jersey. Prepared for Ganes Chemicals, Inc. Media PA. 38 p.

Schmid & Co., Inc. 1998. Wetland conditions along Pascack Road, Lot 2, Block 7706, Paramus Borough, Bergen County, New Jersey. Prepared for the Borough of Paramus. Media PA. 35 p.

Schmid & Co., Inc. 1999. Wetland conditions at the South Valley Road Site, Willistown Township, Chester County, Pennsylvania. Prepared for Richard G. Mingey, Newtown Square PA. Media PA. 44 p.

Schmid & Co., Inc. 1999. Wetland conditions at a site along Amboy Road, Block 7799, Lots 17, 23, and 30, Borough of Staten Island, Richmond County, New York. Prepared for Fred P. Goldhirsch, New York NY. Media PA. 31 p.

Schmid & Co., Inc. 2000. Site conditions at a property along Domorah Drive, Montgomeryville Industrial Park, Montgomery Township, Montgomery County, Pennsylvania. Prepared for Nappen & Associates, Montgomeryville PA. Media PA. 35 p.

Schmid & Co., Inc. 2000. Wetland conditions at a site along Sunfield Avenue in Raritan Center, Block 395, Lot 31.02, Edison Township, Middlesex County, New Jersey. Prepared for Garden State Buildings, L.P., Edison NJ. Media PA. 33 p.

Schmid & Co., Inc. 2000. Wetland conditions at a site along George Davison Road, Block 23, Lots 1, 102.02, 104, and 108, Cranbury Township, Middlesex County, New Jersey. Prepared for MGD Development Group, L.L.C., Hopewell NJ. Media PA. 47 p.

Schmid & Co., Inc. 2000. Environmental impact statement for The Woods at Cranbury, Block 23, Lots 1, 102.02, 104, and 108, Cranbury Township, Middlesex County, New Jersey. Prepared for MGD Development Group, L.L.C., Hopewell NJ. Media PA. 37 p.

Schmid & Co., Inc. 2000. Existing conditions and potential impacts of proposed development at the Pitcher Property along French Creek Road, West Vincent Township, Chester County, Pennsylvania. Prepared for French and Pickering Creeks Conservation Trust, Pottstown PA. Media PA. 20 p.

Schmid & Co., Inc. 2000. Site conditions at a property along Sherwood Avenue, Block 6784, Lots 73, 75, 79, and 81, Borough of Staten Island, Richmond County, New York. Prepared for Robert Kelly, Staten Island NY. Media PA. 31 p.

Schmid & Co., Inc. 2001. Site conditions at a property along Richmond Valley Road, Block 7584, Lot 4, Borough of Staten Island, Richmond County, New York. Prepared for P. De Paulis, Staten Island NY. Media PA. 36 p.

Schmid & Co., Inc. 2001. Wetland conditions at a site along Hutchinson Road and Washington Boulevard, Washington Township, Mercer County, New Jersey. Prepared for P. A. Tafrow, Robbinsville NJ. Media PA. 33 p.

Schmid & Co., Inc. 2001. Wetland conditions at a site known as Lot 13, Block 22, East Windsor Township, Mercer County, New Jersey. Prepared for East Windsor Business Campus Center, L.P., Jenkintown PA. Media PA. 40 p.

Schmid & Co., Inc. 2001. Site conditions at a property along Rustic Lane, Willistown Township, Chester County, Pennsylvania. Prepared for The Meadows at Willistown, LLC, Media PA. Media PA. 35 p.

Schmid & Co., Inc. 2001. Site conditions at a property along PA Route 291, Tinicum Township, Delaware County, Pennsylvania. Prepared for SmartPark Inc., Essington PA. Media PA. 30 p.

Schmid & Co., Inc. 2001. Wetland conditions at Lot 5, Block 46, Tewksbury Township, Hunterdon County, New Jersey. Prepared for Tewksbury/Oldwick Associates, Edison NJ. Media PA. 35 p.

Schmid & Co., Inc. 2001. Wetland conditions at a site known as Block 4801, Lot 5.01, Pennsville Township, Salem County, New Jersey. Prepared for Ganes Chemicals Inc., Pennsville NJ. Media PA. 37 p.

Schmid & Co., Inc. 2001. Site conditions at a property along Father Capodanno, Lot 42, Block 3500, Borough of Staten Island, Richmond County, New York. Prepared for R. Crenshaw, Potomac Falls, Virginia. Media PA. 29 p.

Schmid & Co., Inc. 2001. Site conditions at a property along Quincy and Naughton Avenues, Lot 51, Block 3834, Borough of Staten Island, Richmond County, New York. Prepared for L. S. Huie, Brooklyn, New York. Media PA. 26 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Father Capodanno, Lot 34, Block 3500, Borough of Staten Island, Richmond County, New York. Prepared for S. Krebushevski, Staten Island, New York. Media PA. 27 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Jefferson Avenue, Lots 114 and 116, Block 3864, Staten Island, Richmond County, New York. Prepared for V. Grinberg, Staten Island, New York. Media PA. 43 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Father Capodanno Boulevard, Lot 7, Block 3864, Staten Island, Richmond County, New York. Prepared for L. Huie, Staten Island, New York. Media PA. 35 p.

Schmid & Co., Inc. 2002. Wetland conditions, Reed Sod Farm, Lots 22 and 22.02, Block 43, Upper Freehold Township, Monmouth County, New Jersey. Prepared for MGD Development Group, LLC, Hopewell, New Jersey. Media PA. 43 p.

Schmid & Co., Inc. 2002. Site conditions at Tax Parcels 101 and 102, Tinicum Township, Delaware County, Pennsylvania. Prepared for Tinicum LandVest, LLC, Chester Heights, Pennsylvania. Media PA. 40 p.

Schmid & Co., Inc. 2002. Wetland conditions at a site along Fellowship Road and Church Road, Mount Laurel Township, Burlington County, New Jersey. Prepared for M. Rourke, Fairfax Station, Virginia. Media PA. 39 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Slater Boulevard, Lots 4, 7, 11, and 33, Block 3830, Staten Island, Richmond County, New York. Prepared for S. Krebushevski, Staten Island, New York. Media PA. 37 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Father Capodanno, Lot 30, Block 3500, Borough of Staten Island, Richmond County, New York. Prepared for S. Krebushevski, Staten Island, New York. Media PA. 29 p.

Schmid & Co., Inc. Site conditions at Hamanassett, Chester Heights Borough, Delaware County, Pennsylvania. Prepared for Hamanassett at Darlington LLC, Media, Pennsylvania. Media PA. 37 p.

Schmid & Co., Inc. 2002. Wetland conditions at a site along Blueball Avenue and Interstate 95, Upper Chichester Township, Delaware County, Pennsylvania. Prepared for Moser-Knauer Associates, Boothwyn, Pennsylvania. Media PA. 59 p.

Schmid & Co., Inc. 2002. Site conditions at a property along Aultman Avenue, Lot 5, Block 2262, Staten Island, Richmond County, New York. Prepared for Kling Real Estate, Ltd., Staten Island, New York. Media PA. 52 p.

Schmid & Co., Inc. 2002. Wetland conditions at a site along Naamans Creek and Interstate 95, Upper and Lower Chichester Townships, Delaware County, Pennsylvania. Prepared for Chichester School District, Aston, Pennsylvania. Media PA. 48 p.

Schmid & Co., Inc. 2002. Wetland conditions at the Geisinger Tract, Lots 24, 24-1, and 35, Norwood Borough, Delaware County, Pennsylvania. Prepared for Darby Realty, Inc., and the Estate of Faye L. Goodman, Springfield, Pennsylvania. Media PA. 45 p.

Schmid & Co., Inc. 2003. Site conditions at the Valley Park Business Center, Hillsborough Township, Somerset County, New Jersey. Prepared for SAI Middlesex Farms, LP, Edison, New Jersey. Media PA. 43 p.

Schmid & Co., Inc. 2003. Wetland conditions at the Hillsborough Business Center, Lot 1.09, Block 58, Hillsborough Township, Somerset County, New Jersey. Prepared for SAI Middlesex Farms, LP. Edison, New Jersey. Media PA. 43 p.

Schmid & Co., Inc. 2003. Site conditions at a property along Aultman Avenue, Lots 3, 4, and 7, Block 2261, Staten Island, Richmond County, New York. Prepared for P. Zahakos, Rosedale, New York. Media PA. 43 p.

Schmid & Co., Inc. 2003. Wetlands at a property along Little Britain Road, Section 97, Block 1, Lot 40.1, Town of Newburgh, Orange County, New York. Prepared for Ginsburg Development LLC, Pomona, New York. Media PA. 36 p.
Schmid & Co., Inc. 2003. Site conditions at a property along Mace Street, Lot 9, Block 2259, Borough of Staten Island, Richmond County, New York. Prepared for P. Grima, Staten Island, New York. Media PA. 39 p.
Schmid & Co., Inc. 2003. Wetlands at a property along Golf Links Road, Section 73, Block 1, Lots 31.2, 33.2, and 33.3, Town of Wallkill, Orange County, New York. Prepared for Ginsburg Development, LLC, Pomona, New York. Media PA 41 p.
Schmid & Co., Inc. 2003. Application for Letter of Interpretation (Presence/Absence), Lots 19 and 20, Block 5601, Lawrence Township, Mercer County, New Jersey. Prepared for C. and S. Costa, Lawrenceville, New Jersey. Media PA. 40 p.
Schmid & Co., Inc. 2003. Wetland conditions at a site along South Broad Street, Lot 23, Block 2363, Hamilton, New Jersey. Prepared for J. Seefeldt, Hamilton, New Jersey. Media PA. 37 p.

Schmid & Co., Inc. 2004. Wetland conditions at a site along Columbia Turnpike, Lots 9 and 16, Block 2002, Florham Park Borough, Morris County, New Jersey. Prepared for R. DiPopolo, Belleville, New Jersey. Media PA. 48 p.
Schmid & Co., Inc. 2004. Wetland conditions at the Hoffman Road site, Lots 10, 11.01, 19.02, and 20, Block 32, Monroe Township, Middlesex County, New Jersey. Prepared for Whitherb Associates, Inc., Dayton, New Jersey. Media PA. 49 p.
Schmid & Co., Inc. 2004. Wetland conditions at the Merk Tract, Lot 1.02, Block 1504, Hamilton Township, Mercer County, New Jersey. Prepared for Grez & Kaluzny Land Development, LLC, Hamilton, New Jersey. Media PA. 36 p.
Schmid & Co., Inc. 2004. Wetland conditions at a site along Christmas Tree Lane, Lot 51, Block 4701, Pennsville Township, Salem County, New Jersey. Prepared for M. Staci, Wilmington, Delaware. Media PA 46 p.
Schmid & Co., Inc. 2004. Wetland conditions at the Prospect Hill site along NY Route 17A, Town of Goshen, Orange County, New York. Prepared for Ginsburg Development LLC, Pomona NY. Media PA. 49 p.
Schmid & Co., Inc. 2004. Wetland conditions at a site along Mullica Hill-Woodstown Road, Harrison Township, Gloucester County, New Jersey. Prepared for Ginsburg Development LLC, Hopewell, New Jersey. Media PA. 42 p.

Schmid & Co., Inc. 2005. Wetlands at Britain Commons, Sections III and IV, Town and City of Newburgh, Orange County, New York. Prepared for Ginsburg Development, LLC, Pomona, New York. Media PA. 41 p.
Schmid & Co., Inc. 2005. Application for General Permit #6, Lots 24 and 31, Block 501, Logan Township, Gloucester County, New Jersey. Prepared for Logan Sand & Gravel, Bridgeport, New Jersey. Media PA. 68 p.
Schmid & Co., Inc. 2005. Wetland conditions at the West Tract, Washington Township, Berks County, Pennsylvania. Prepared for Barto Mall, Inc., Newtown Square, Pennsylvania. Media PA. 59 p.

Schmid & Co., Inc. 2006. Wetland conditions at a site along Camptown Drive at Kuntz Avenue, Lot 18, Block 301, Berkeley Heights Township, Union County, New Jersey. Prepared for Ramesh Raman. Media PA. 36 p.
Cahill & Associates, Schmid & Co., Inc, and PennFuture. 2006. Natural conservation area analysis for the Elwyn tract, Middletown Township, Delaware County, Pennsylvania. Prepared for Middletown Township Land Conservancy and Chester-Ridley-Crum Watershed Association. Media PA. 8 p. www.pennfuture.org/UserFiles/ElwynConservationAreaAnalysis.pdf.
Schmid & Co., Inc. 2006 Freshwater wetland permit application for water wells, Prospect Hill property, Town of Goshen, Orange County, New York. Prepared for GDC Group. Media PA. Variously paged (33 p.).
Schmid & Co., Inc. 2006. Wetland conditions at 623 Texas Road, Old Bridge and Marlboro Townships, Middlesex and Monmouth Counties, New Jersey. Prepared for Garden Plaza LLC. Media PA 36 p.
Schmid & Co., Inc. 2006. Application for transition area averaging waiver for Lot 5.03, Block 409, Lower Township, Cape May County, New Jersey. Prepared for Dominick Paglione. Media PA. Variously paged (36 p).
Schmid & Co., Inc. 2006. Wetland conditions at a site along Fellowship Road, Church Road, Beaver Avenue, and Route 73, Mount Laurel Township, Burlington County, New Jersey. Prepared for Develcom. Media PA. 42 p.
Schmid & Co., Inc. 2006. Wetland conditions at a site along Preston and Sycamore Avenues, Lots 12, 13, 14, and 15, Block 14, Voorhees Township, Camden County, New Jersey. Prepared for Voorhees Preston LLC. Media PA. 53 p.

Schmid & Co., Inc. 2007. Wetland conditions at a site along Worthington Mill Road, Wrightstown Township, Bucks County, Pennsylvania. Prepared for Brian Bentley. Media PA. 38 p.
Schmid & Co., Inc. 2007. Wetland conditions at a site in Hatfield Township, Block 77, Montgomery County, Pennsylvania. Prepared for Hatfield 309 LLC. Media PA. 69 p.
Schmid & Co., Inc. 2007. Wetland conditions at a site along PA Route 309 (Bethlehem Pike) near Bergey Road, Block 76, Hatfield Township, Montgomery County, Pennsylvania. Prepared for Hatfield 309 LLC. Media PA. 42 p.
Schmid & Co., Inc. 2007. Application for General Permits 1, 2, and 10A, Lot 51, Block 4701, Pennsville Township, Salem County, New Jersey. Prepared for Robert Mistichelli, Pennsville NJ. Media PA. 35 p.

Schmid & Co., Inc. 2008. Freshwater wetland application for General Permits 7 and 11, Towneplace Hotel, Lot 13, Block 2301, Logan Township, Gloucester County, New Jersey. Prepared for SSN Hotel Management, LLC. Newark DE. Media PA. 52 p.
Schmid & Co., Inc. 2008. Application for General Permit 7 and Transition Area Averaging Waiver, Lots 2 and 3, Block 134, Town of Kearny, Hudson County, New Jersey. Prepared for Arlington Cemetery Association, Kearny NJ. Media PA. 69 p.
Schmid & Co., Inc. 2008. Review of a petition to redesignate Grinnage Run from HQ-WWF to WWF, South Fork Tenmile Creek basin, Gray Township and Richhill Township, Greene County, Pennsylvania. Prepared for Center for Coalfield Justice, Mountain Watershed Association, and Citizens for Pennsylvania's Future. Media PA. 26 p. www.schmidco.com
Schmid & Company, Inc. 2008. Freshwater wetland application for letter of interpretation extension, Dunhams Corner Road Site, Block 22.010, Lot 2.03, South Brunswick Township, Middlesex County, New Jersey. Prepared for Creative Communities LLC. Media PA. 46 p.

Schmid & Co., Inc. 2009. Review of a petition to redesignate tributaries to South Fork Tenmile Creek from HQ-WWF to WWF, Center and Jackson Townships, Greene County, Pennsylvania. Prepared for Citizens for Pennsylvania's Future. Media PA. 28 p.

Schmid & Company, Inc. 2010. A need to identify "Special Protection" status and apply existing use protections to certain waterways in Greene and Washington Counties, Pennsylvania. Prepared for Citizens Coal Council. Media PA. 15 p. plus appendix.

Schmid & Co., Inc. 2011. The increasing damage from underground coal mining in Pennsylvania, a review and analysis of the PADEP's Third Act 54 Report. Prepared for Citizens Coal Council, Bridgeville PA. Media PA. 50 p. http://www.schmidco.com/17April2011SchmidAct54Analysis.pdf

Schmid & Co., Inc. 2011. Comments on DESA Permit Application E5729-014. Perpared on behalf of the Foundation for Pennsylvania Watersheds. Media PA. 24 p.

Schmid & Co., Inc. 2012. Individual freshwater wetland permit application, Lot 2, Block 2301, Paramus Borough, Bergen County, New Jersey. Prepared for George Washington Memorial Park Cemetery Association. Media PA. 90 p.

Schmid & Company, Inc. 2012. Comments to Pittsburgh District Army Corps of Engineers on Application CELRP-OP-F 2007-891 for proposed Foundation Mine. Center and Jackson Townships, Greene County, PA. Media PA. 17 p.

Schmid & Co., Inc. 2013. Review of Foundation Mine, a new longwall mine. Prepared for Greene County Watershed Association, Waynesburg PA. 60 p.

Schmid & Co., Inc. 2013. Existing conditions at a site along Dey Road, Lot 5, Block 5, Cranbury Township, Middlesex County NJ. Prepared for Skyhail LLC, Bayonne NJ. 28 p. plus attachments.

Schmid & Company, Inc. 2013. Review of permit applications of Amerikohl Mining Inc. for proposed Walters Mine, Donegal Township, Butler County, Pennsylvania. Prepared for Citizens Coal Council, Bridgeville PA. Media PA. 35 p.

Schmid& Co., Inc. 2014. Summary review of Foundation Mine. Prepared for Greene County Watershed Association. Waynesburg PA. 15 p.

Schmid & Co., Inc. 2014. The illusion of environmental protection: permitting longwall coal mines in Pennsylvania. Prepared for Citizens Coal Council, Bridgeville PA. 138 p.

Schmid & Co., Inc. 2015. Undermining the public trust: a review and analysis of PADEP's Fourth Act 54 Five-year Assessment report. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 67 p.

Schmid & Co., Inc. 2015 . Comments on Docket ID: OSM–2010–0018 (Proposed Stream Protection Rule). Prepared Foundation for Pennsylvania Watersheds, Alexandria PA. Media PA. 36 p.

Schmid & Company, Inc. 2015 . Regulated waters and wetlands at the Fairview Golf Redevelopment site, Ridley Township, Delaware Schmid & Company, Inc. 2016. Wetland and stream impacts of Sunoco's Mariner East II pipeline. Prepared for Mountain Watershed Association and the Clean Air Council. Media PA. 22 p.

Schmid & Company, Inc. 2016. Longwall mining A to Z: learning from the Pennsylvania experience. Prepared for the Citizens Coal Council, Bridgeville PA. Media PA. 56 p.

Schmid & Company, Inc. 2015 . Regulated waters and wetlands at the Fairview Golf Redevelopment site, Ridley Township, Delaware County, Pennsylvania. Prepared for Everest EB-5 Capital LLC, Havertown, Pennsylvania. Media PA. 46 p.

Schmid & Company, Inc. 2016. The effects of the proposed PennEast pipeline on exceptional value wetlands in Pennsylvania. Prepared for the Delaware Riverkeeper Network, Bristol, PA. Media PA. 54 p.

Schmid & Company, Inc. 2016. Comments on FERC DEIS for PennEast Pipeline Project in New Jersey. Prepared for the Delaware Riverkeeper Network, Bristol, PA. Media PA. 15 p.

Schmid & Company, Inc. 2017. A comparison of the water resource impacts associated with alternative alignments of the proposed Atlantic Sunrise pipeline on and near the Nesbitt property, Luzerne and Wyoming Counties, Pennsylvania. Prepared for Icarus Ecological Services, Inc., Saint Augustine, FL. Media PA. 23 p.

Schmid & Company, Inc. 2017. Potential impacts of Mariner East II pipelines on wetlands, streams, and water supplies in Middletown Township and Delaware County, Pennsylvania. Prepared for Middletown Coalition for Community Safety. Media PA. 18 p.

Schmid & Company, Inc. 2017. Potential impacts of the Atlantic Sunrise pipeline on exceptional value wetlands and special protection waters in Schuylkill County, Pennsylvania. Prepared for Delaware Riverkeeper Network, Bristol, PA, and Schuylkill Pipeline Awareness, Schuylkill County, PA. Media PA. 21 p

Schmid & Company, Inc. 2017. Stream protection in Pennsylvania in the context of underground coal mining. Prepared for Citizens Coal Council, Cannonsburg, PA. Media PA. 30 p.

Current address

Director
Rushing Rivers Institute
592 Main Street
Amherst, MA 01002
tel. (413) 687 4740
fax and voice: (208) 693 9330
e-mail:Piotr@RushingRivers.org

http://en.wikipedia.org/wiki/Piotr_Parasiewicz

Synopsis

Piotr Parasiewicz was born in Warsaw in 1961 as a son of chemical engineers Dr. Wanda and Kazimerz Parasiewicz. He completed K. Gottwald High School (currently S. Staszic) in Warsaw and started his higher education at the University of Agricultural Sciences in Warsaw (SGGW). In 1982 he left the country and continued his education as a civil and environmental engineer at the University of Agricultural Sciences in Vienna. He started his career in 1988 as a research associate in an interdisciplinary team of biologists, water engineers and landscape ecologist at the Department of Hydrobiology, Fisheries and Aquaculture of the same University. This position strongly influenced his professional development and provided him with multidisciplinary expertise on **river ecology and restoration engineering**. He was a member of the Austrian Network for Environmental Research advising the Austrian Government on the development of EU environmental and research policy, and actively participated in shaping the EU Water Framework Directive.
In 1999 he received a David H. Smith Fellowship from The Nature Conservancy in the USA, and began his career as a research Professor at Cornell University and later University of Massachusetts, Amherst and Mount Holyoke College. In 2007 he founded the Rushing Rivers Institute, a river research non-profit (www.RushingRivers.org) where he serves as a Director. He is also currently an Adjunct Professor at the University of Nebraska, Lincoln.
Dr. Parasiewicz's career is strongly affected by cross disciplinary collaborations worldwide. He is the creator of the International Aquatic Modeling Group (IAMG), a researcher network aiming to improve knowledge on running water habitats. For his strong aptitude as the president of IAMG in 1999 he received funding from the European Science Foundation that supported COST Action 626: European Aquatic Modelling Network. Scientists from over 40 countries participated in the network, which spawned a number of collaborative publications and international projects. Dr. Parasiewicz's research is supported by federal and state governments, non-profit organizations and industries. Dr.

Parasiewicz frequently serves as a technical advisor for State and Federal Governments in the USA and abroad.

Research expertise and interests

River science and restoration engineering: Instream flow and habitat modeling, river restoration and management, Fish ecology and fisheries management, Fish passage, River Survey and Instrumentation, Geographical Information Systems (GIS), Remote sensing, Digital Terrain Models (DTM), environmental statistics, computer programming, Computer Aided Design (CAD).

Scientific accomplishments:

Dr. Parasiewicz is an applied scientist dedicated to research necessary for sustainable management of running waters. He combines engineering with ecological sciences and developing tools for effective restoration and management planning. He is best known for his development of **MesoHABSIM** (www.MesoHABSIM.org), a multiscale approach for instream habitat modeling. MesoHABSIM is currently used in river restoration and planning worldwide, particularly in the USA, Europe and recently New Zealand. His other scientific accomplishments are among others:

- concept of Virtual River Model,
- concept of Bioperiods,
- concept of Upscalling in habitat modeling,
- Geodetically Based Irregular Sampling protocol for river surveys,
- development of multiplex survey instrument Depth Velocity Position Bar,
- Uniform Continuous Under Threshold Analysis of Habitat Time Series,
- Habitat Meter
- conceptual guidelines for construction and planning of nature-like fish bypass channels.

The results and ideas are published as 68 scientific papers (20 in highly ranked peer reviewed journals) and on-line.

Education:

1998 - Ph. D. (Doctor rerum naturalium technicarum, doctor of science *summa cum laude*) Natural Resources Management and Water Engineering, University of Agricultural Sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and ao. Univ. Prof. Dr. Stefan Schmutz.

1993 - G. E. (Dipl. Ing.), Environmental and Water Engineering, University of Agricultural sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and Univ. Prof. Dr. Siegfried Radler.

1988 - B.S., Environmental and Water Engineering, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

Memberships in professional societies

International Aquatic Modeling Group,
American Fisheries Society
International Society for River Science
River Management Society

Academic appointments

2007-pres. Rushing Rivers Institute, Director.

2009–pres. University of Nebraska, Lincoln, NE

Adjunct Professor, School of Natural Resources

2007-2009. Mt. Holyoke College, Mt. Holyoke, MA

Research Associate and Adjunct Professor, Department of Earth and Environment

2004-2007 University of Massachusetts, Amherst, MA
Research Associate Professor, Department of Natural Resources Conservation

2003-2007 University of Connecticut, Storrs, CT
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Management and Engineering

2000-2004 Cornell University, Ithaca, NY
Research Associate IV. Department of Natural Resources. Director, Instream Habitat Program

2000-2004 University of Massachusetts, Amherst, MA
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Conservation.

1999-2000 Cornell University, Ithaca, NY
Post Doctoral Fellow, Aquatic Ecological Engineering, New York Cooperative Fish and Wildlife Research Unit

1998-1999 University of Agricultural Sciences, Vienna, Austria
University Lecturer, Institute of Water Provision, River Ecology and Waste Management Department of Hydrobiology, Fisheries and Aquaculture

1994-1998 University of Agricultural Sciences, Vienna, Austria
Research Associate, Institute of Water Provision, River Ecology and Waste Management. Department of Hydrobiology, Fisheries and Aquaculture

1988-1994 Research Assistant, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria

Honors and awards

2007 – US Government. Residency as an individual of extraordinary abilities.

2006 - American Fisheries Society - Certified Fisheries Professional

2005 – Microsoft Research Grant: A Tiered Smart Client System for Annotating the Land-Water Interface: Enabling Scientific Simulation. Together with Chris Pal. $50,000

1999 - The Nature Conservancy: David H. Smith Fellowship - International Collaborations. $25,000.

1998 - *Summa Cum Laude*

1993 - First award and grant „*100 Jahre Kulturtechnik und Wasserwirtschaft*" for Master Thesis : CAD-application in eco-morphological investigations of running waters. - Eternit ATS 10,000

Special training courses

1994 – Instream Flow Incremental Methodology (IFIM) - Stream Habitat Sampling Techniques" Colorado State University, Ft. Collins, CO
1994 - "Using Computer-Based Physical Habitat Simulation (PHABSIM) System", Utah State University, Logan, UT

Languages

Fluent in Polish, Russian, German, English
Passive knowledge of Hungarian and Arabic

Current and recent research projects

- An Instream Flow Assessment of the Little River, CT, Town of Putnam.3/2010-3/2011. $159,000
- Developing Environmental Flows in the Niobrara River for Fish and Wildlife. Nebraska Department of Games and Parks. 7/2009-6/2011. Co-PI with M.Pegg. $795,050
- An interactive, GIS-based application to estimate target fish communities in Northeastern streams. Regional Conservation Needs. Northeast Association of Fish and Wildlife Agencies. 1/2009-12/2010. $64,000.
- Development of a mitigation method and ecological impacts offset for spring water withdrawals on downstream habitats for fish and invertebrates. Reconnaissance study on Wekepeke Brook. Nestlé Corporation. 6/2008-5/2010. $200,000
- Development of Draft Environmental Flow Recommendations for the Saugatuck River Watershed. The Nature Conservancy 6/2008-3/2009. $50,000.

Past Research Projects (since arrival in US 1999)

- Pine Brook Habitat Assessment and Restoration Planning – reconnaissance survey. Mass. Riverways Program. 4/2008-6/2008. $15,000.
- Using hydromorphological signatures to determine flow related habitat thresholds for instream communities. Co-PI with Christina Cianfrani of Hampshire College. USGS 3/2006-3/2008. $50,000
- Instream flow studies and watershed management plan for the Lamprey River Designated Reach. New Hampshire Department of Environmental Services. Co-PI with Don Kretchmer, Normandeau Associates and Tom Ballestero, University of New Hampshire. 8/05-12/07. $250,000
- Validation of In-Stream Habitat Models for the Fenton River, Storrs, Connecticut. Connecticut Department of Environmental Protection. Co-Pi with Glen Warner. 7/05-5/07. $71,000.
- Dwarf Wedgemussel Habitat Study on the Upper Delaware River. US Fish and Wildlife Service 6/05 – 12/08. $631,000
- Instream flow studies and watershed management plan for the Souheagan River Designated Reach. New Hampshire Department of Environmental Services. Co-PI with Tom Ballestero, University of New Hampshire and Don Kretchmer, Normandeau Associates. 6/04-5/06. $250,000
- Eightmile River Instream Flow Study. National Park Service. 2/04/-5/06. $87,000
- Developing a sustainable management plan for the Pomperaug River watershed. Phase II. Pomperaug River Watershed Coalition. Principal Investigator. 3/04-1/06. $55,000
- Feasibility study of removal of Hatfield Dam – Hatfield, MA. Massachusetts Environmental Trust. Co-Principal Investigator (with S. Jackson). $30,000

- Fish habitat study for Long-Term Impact Analysis of the University of Connecticut’s Fenton River Water Supply Wells on the Habitat of the Fenton River. University of Connecticut. Principal Investigator. 4/03-8/05. $46,300

- Defining restoration needs for Beartrap Creek. Onondaga Lake Partnership and Isaak Walton League. Principal Investigator. 6/03-12/03. $4,700
- Instream habitat evaluation of Santee River, South Carolina below Wilson Dam. Santee Cooper AG. Principal Investigator. 1/03-1/05. $250,000
- Developing a sustainable management plan for the Pomperaug River watershed. Pilot study. Connecticut Department of Environmental Protection. Principal Investigator. 6/02-10/03. $25,000
- Application of MesoHABSIM on Stony Clove – PHASE I and Demonstration of integrating instream habitat assessment into local watershed management. Green County Soil and Water Conservation District and New York City Department of Environmental Protection. Principal Investigator. 6/02-8/03. $43,800
- Demonstration of integrating instream habitat assessment into local watershed management. New York State Water Resources Institute. Principal Investigator. 3/01-2/02. $18,000
- Conservation planning on the Mill River on Hatfield. The Nature Conservancy and Massachusetts Environmental Trust. Principal Investigator. 11/2001-10/2002. $24,000
- Instream Flow Requirements of Mill River – Hatfield, MA. Massachusetts Department of Environmental Management. Co-Principal Investigator (with S. DeStefano and S. Jackson). 6/2000-6/2001. $30,000
- River Scale Instream Flow Simulation - New York State Water Resources Institute. Principal Investigator. 3/2000-2/2001. $6,000
- Ecohydrology study of Quinebaug River. Principal Investigator. New England Interstate Water Pollution Control Commission. Principal Investigatior. 10/1999-12/2003. $508,000
- International Network to Harmonize and Improve Knowledge and Assessment Methods of Biotic-Abiotic Interactions in Running Waters as a Conservation Tool. The Nature Conservancy. Principal Investigator. 12/1999-12/2000. $25,000

Select professional services

Scientific advisor:

National Oceanic and Atmospheric Administration. Reviewer of fish passage barriers manual. 2010.

Massachusetts Executive Office of Environmental Affairs. Sustainable Water Initiative Technical Subcommittee. Boston, MA. 2009-present.

River Network Science Task Force. USA. 2009

Connecticut Department of Environmental Protection. Science and Technical Workgroup on Water Flow Regulations for the State, Hartford, CT 2006 – 2007

American Fisheries Society. Bioengineering Section. Education committee for development of fluvial engineering curriculum. USA. 2002 -2004

Potomac River Basin Commission. Potomac Minimum Instream Flow Methods Workshop, Potomac, MD. 4/8-9/2003

Rhode Island Water Resources Board. Water Allocation Program Advisory Council, Providence, RI, 2003

New York Department of Environmental Conservation. Hydrological Habitat Modification workgroup of Non-Point Source Pollution Committee, Albany, NY. 2001-2004

Connecticut Water Planning Council Technical Committee . New Britain, CT 6/30/2002

Austrian Network for Environmental Research. River Ecology Sub-network 1997-99

Invited speaking engagements:

Keynote for EUROMECH Colloquium 523 Clermont-Ferrand, France, 15-17 June, 2011

Leibniz-Institute of Freshwater Ecology and Inland Fisheries. Seminar on Application of MesoHABSIM. Berlin. 10/4/2010

New Zealand Regional Council of Governments. 2 Day Seminar on Application of MesoHASBIM approach.

ETH Zurich. Seminar on Application of MesoHABSIM. Kastanienbaum, Switzerland. 10/30/2009.

EPFL Lausanne. Seminar Use of the Mesohabitat Simulation Model (MesoHABSIM) for Instream Habitat Assessments, Lausanne, Switzerland. 10/29/2009.

University of Montreal. Application of MesoHABSIM model and habitat time series analysis for flow management and river restoration. Montreal, Canada. 1/25/2009.

Polish Ministry of Industrial Development. Contemporary techniques in River management. Warsaw, Poland 5/22/05

European Commission. European Aquatic Modelling Network. Final conference of COST Action 626 in Silkeborg, Denmark 5/19-20/2005

NOAA Restoration Center. "Connecting science to Application". 4/13/05

Institute of Ecosystem Studies. Conference Hudson River Tributaries: the State of Our Knowledge. Millbrook, NY. 6/12/2003.

INRS Eau terre et Environnement, Canada. International workshop on "State of the art in habitat modeling and conservation flows", Quebec City, Canada. 3/4 -5/2003

Iowa Institute of Hydraulic Research. Workshop Hydroscience and Engineering, The University of Iowa, Iowa City, IA. 2/7/2003

New York Chapter of American Fisheries Society. "Restoring Natural Flow Regimes: Dam Removal as a Tool in River Restoration" Canandaigua, NY. 1/9/2003

European Science Foundation. "Upscaling Workshop" of COST Action 626: "European Aquatic Modelling Network", Gent, Belgium. 12/11-13/2002

Massachusetts River Restore Program. Environmental Risk for Dams, Marlborough, MA. 11/19/2002

University of Wisconsin-Madison. Engineering Innovative Fish Passage Dam Removal and Nature-like Fishways, Waterville Valley, NH. 10/20-10/24/2002

American Fisheries Society – Organizing committee of Fisheries Bioengineering Symposium, Baltimore, MD. 8/25-30/2002

New England Interstate Water Pollution Control Commission. Instream Habitat Program, New London, CT 5/16/2002

Nebraska Department of Game and Parks. Platte River Workshop. Pallid Sturgeon/Sturgeon Chub Task Force. Lincoln, NE 1/23-24/2002

The Nature Conservancy. Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO 7/30-8/2/2001

European Science Foundation. COST Action 626 "European Aquatic Modelling Network", Trondheim, Norway, 5/11-12/2001

University of Oslo, Norway. Zoological Museum of University of Oslo, Oslo, Norway. 5/8/2001

US Fish and Wildlife Service. Eastern Hydropower Licensing Workshop Northeast and Southeast Regions. National Conservation Training Center, Shepherdstown, WV, 8/29–31/2000

HydroVision 2000 Conference. Session: International Water Power Regulations and Compliance, Charlotte, NC, August 2000

Instream Flow Council. National Meeting. Higgins Lake, MI. 5/22-24/2000.

US Army Corps of Engineers. Worksop "Passage for Non-Salmonid Fishes in Streams and Rivers: A Critical Element in Ecosystem Management and Restoration", Wilmington, NC, 4/25-4/27/2000

US Fish and Wildlife Service. Roanoke River hydropower licensing workshop, Raleigh, NC.11/30-12/2/99.

European Commission. International workshop "Water Related Conflicts: Research Deficits and Demands" in preparation of Fifth Framework Program. Katowice, Poland 1998.

For profit consulting and professional services.

2009	Stroughan Environmental. Expert review of White Marsh fishway design.
2008	Trout Unlimited and Connecticut River Watershed Council Expert witness for Appeal of Massachusetts Department of Environmental Protection permitting of Biomass Gasification Project in Russell, MA
2008	Friends of Quinebaug River Expert witness for Connecticut Department of Environmental Protection Review of the proposed Biomass Gasification Project in Plainfield, CT.
2008	Residents for Alternatives to Trashing Southbridge Expert witness for Board of Health Review of the proposed expansion of the Southbridge Landfill.
2007/2008	Trout Unlimited Consultant. Impact of planned Yale Farm Golf Club on the ecology of adjacent streams.
2004	Trout Unlimited Expert witness for Issues Conference for the Belleayre Project at Catskill Park
2003	US Army Corps of Engineers. Consultant. Habitat Restoration Team an oversight committee of Onondaga Lake Watershed Restoration project, Syracuse, NY.
2002	Natural Resources Council of Maine. Consultant. Review of existing by-pass channels for dam removal study. Augusta, ME.
2002	US Bureau of Reclamation Consultant. Expertise on fish passage options at San Acacia Dam on Middle Rio Grande River, Albuquerque, NM.
2002	US Fish and Wildlife Service. Consultant. Expertise on instream flow settings on the Santee River below Willson Dam, FERC re-licensing project, Charleston, SC.
2001-2002	US Army Corps of Engineers. Consultant. Supervision of planning of nature-like bypass channel on Lock and Dam Number 1 on the Cape Fear River, Wilmington, NC.

2001-2002 US Fish and Wildlife Service.
Consulting expert for construction of fish-passage facility on New Savannah Bluff Dam, Savannah River, Augusta, GA.

2001 Trout Unlimited.
Consultant. Report: Instream flows of the Upper Delaware River, Roscoe, NY.

Teaching experience

2008-2009 Technical University of Madrid, Spain
MesoHABSIM: Instream Data collection and modeling.

2007-2009 Rushing Rivers Institute, Amherst
MesoHABSIM: Instream Data collection and modeling.
MesoHABSIM Approach and Application
MesoHABSIM Computation and SIM-Stream Software
MesoHABSIM Field Techniques

2004-2007 University of Massachusetts
NRC 597R: MesoHABSIM: Instream Data collection and modeling.
Guest lecturer: WFCON 597W Wetland Conservation

2001-2003 Cornell University.
Guest lecturer NTRES 110, Introduction to the Field of Natural Resources, Department of Natural resources
Guest lecturer BEE 371, Hydrology and the Environment Department of Biological and Environmental Engineering,.

1995 -1999 University of Agricultural Sciences, Vienna
"Eco-morphology of running waters" within the hydrobiology lab. This practical course enrolled annually over 200 undergraduate and graduate students. It took place in Lunz am See in the Austrian mountains, and consisted of lectures and field work.

<u>Professional education courses in US:</u>

US Fish & Wildlife Service, National Conservation Training Center – Invited instructor for Fish Passageways & Bypass Facilities-East Course, Hadley, MA, measure and Nature-like bypass channels. 7/10/2000

University of Wisconsin-Madison - invited lecturer Engineering Innovative Fish Passage Dam Removal and Nature-like Fishways, Waterville Valley, New Hampshire, 10/20-10/24, 2002.

University of Wisconsin-Madison - invited lecturer. Urban Channel Design and Rehabilitation: Biotechnical engineering, Watershed concepts, recapturing the stream corridor, Engineering alternatives, Madison, Wisconsin, 11/28-11/30, 2000

PUBLICATIONS AND REPORTS

Dissertations

PARASIEWICZ P. 1998. Computer aided methods for biological investigations of hydro-morphological attributes of running waters – Selected aspects of data collection and analysis. Ph. D. Dissertation. Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

PARASIEWICZ P. 1993. CAD-application in eco-morphological investigations of running waters. Master Thesis. Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

Refereed articles

1. VEZZA P., PARASEWICZ P., ROSSO M., COMOGLIO C., (in press). Defining environmental flows requirements at regional scale by using meso-scale habitat models and catchments classification. *Rivers Research and Application.*
2. GORTÁZAR J, PARASIEWICZ P., GONZÁLEZ C. A. & D. G. DE JALÓN (in press). Physical habitat assessment in the river tajuña (Spain) by means of the mesohabsim approach. Limnetica special volume in river habitats.
3. PARASIEWICZ P., RUBIAL J. G., SANCHEZ M. M. & D. G. DE JALÓN (2009) Mesohabsim: an effective tool for river and watershed management [Mesohabsim: una herramienta eficaz para la gestión de ríos y cuencas fluviales]. Tecnologia del Agua. **29** (309):20-26.
4. JACOBSON R. A., WARNER G., PARASIEWICZ P., BAGTZOGLOU R. & F. OGDEN (2009) An Interdisciplinary Study of the Effects of Groundwater Extraction on Freshwater Fishes. *International Journal of Ecological Economics & Statistics*. **12** (F08) :7-26.
5. PARASIEWICZ P. (2008): Habitat time-series analysis to define flow-augmentation strategy for the Quinebaug River, Connecticut and Massachusetts, USA. *River Research and Application.* **24**: 439–452.
6. PARASIEWICZ P. (2008): Application of MesoHABSIM and target fish community approaches for selecting restoration measures of the Quinebaug River, Connecticut and Massachusetts, USA. *River Research and Application.* **24**: 459–471.
7. PARASIEWICZ P. (2007): The MesoHABSIM Model Revisited. *River Research and Application* **23** (8):893-903.
8. PARASIEWICZ P. & J. D. Walker (2007): Comparing and testing results of three different micro and meso river habitat models. *River Research and Application* **23** (8): 904-923.

9. PARASIEWICZ P. (2007): Developing a reference habitat template and ecological management scenarios using the MesoHABSIM model. *River Research and Application* **23** (8): 924-932.

10. NADIM F., BAGZTZOGLO A. C., BAUN S.A., WARNER G., JACOBSON R. A. & P. PARASIEWICZ (2007): Management of adverse impact of a public water supply well-field on the aquatic habitat of a stratified drift stream in eastern Connecticut, *Water Environment Research.* **79** (1) 43-56(14).

11. WERLE S. F., JOHNSON N.A., DUMONT E. R. & P PARASIEWICZ (2007): Nei's ecological distance analysis: a novel use of Nei's modified genetic distance (DA). Northeastern Naturalist **14**(3):439–446.

12. PARASIEWICZ P. (2003): Upscaling: Integrating habitat model into river management. *Canadian Water Resources Journal.* Special Issue: State-of-the-Art in Habitat Modelling and Conservation of Flows **28** (2) p. 283-300.

13. PARASIEWICZ P. (2001): MesoHABSIM - a concept for application of instream flow models in river restoration planning. *Fisheries* **29** (9) p. 6-13.

14. PARASIEWICZ P. & M. J. DUNBAR (2001): Physical habitat modelling for fish – a developing approach - *Archiv für Hydrobiologie*. Suppl. (Large Rivers Vol. **12**), 135/2-4 p. 239-268. PARASIEWICZ P., HOFMANN H. C. & B. HÖGLINGER (1999): The DVP - Depth Velocity Position Bar - a multiplex instrument for physical habitat measurements in small riverine domains - *Regulated Rivers: Research and Management,* **15**, 77-86.

15. PARASIEWICZ P., HÖGLINGER B. &. H. C. HOFMANN (1998): Der DVP – Stab. Depth Velocity Position Bar – Ein multifunktionales Gerät für morpphometrische Aufnahmen an Fließgewässern – *Österreichs Fischerei,* Jahrgang 51, **10**, 232-239.

16. PARASIEWICZ P., SCHMUTZ S. & O. MOOG, (1998): The effects of managed hydropower peaking on the physical habitat, benthos and fish fauna in the Bregenzerach, a nival 6th order river in Austria, *Fisheries Management and Ecology*, 1998, **5**, 403-417.

17. SCHMUTZ S., MOOG O. & P. PARASIEWICZ (1997): Bewertung der ökologischen Funktionsfähigkeit in Ausleitungsstrecken - zoozönotischer Ansatz.- *Wasserwirtschaft* 87 (7-8): 354-355.

18. PARASIEWICZ, P. (1996): Estimation of physical habitat characteristics using automation and geodesic-based sampling. *Regulated Rivers: Research & Management*, Vol. 12, 575-583.

19. SCHMUTZ S., PARASIEWICZ P., KAUFMANN M., & G. PARTL, (1995): Bewertung der ökologischen Funktionsfähigkeit in Ausleitungsstrecken anhand von Fischzönosen. *Wasserbau-Mitteilungen der Technischen Hochschule Darmstadt*, Nr. 40:191-207.

Book Chapters

20. PARASIEWICZ, P., N. GILLESPIE, D. SHEPPARD & T. WALTER (2010) Strategy for Sustainable Management of the Upper Delaware River Basin. In: F. De Carlo and A. Bassano (ed). Freshwater Ecosystems and Aquaculture Research. Nova Science Publishers, Inc. pp. 249-264. ISBN: 978-1-60741-707-1.
21. PARASIEWICZ, P., J. NESTLER, N.L. POFF & A. GOODWIN. (2008) Virtual Reference River: A Model for Scientific Discovery and Reconciliation. 2008. In: M. S. Alonso, I. M. Rubio (ed) Ecological Management: New Research, Nova Science Publishers, Inc. pp. 189-206. ISBN: 978-1-60456-786-1
22. BORSÁNYI P. & PARASIEWICZ, P. (2004): Contrasting two individually developed, meso-scale based habitat evaluation systems. In Fifth International Symposium on Ecohydraulics. Aquatic Habitats: Analysis & Restoration (eds D.G.d. Jalón & P.V. Martínez), Vol. 2, pp. 845-850. IAHR, Madrid, Spain.
23. WILDMAN L, PARASIEWICZ P., KATOPODIS C. & U. DUMONT 2003. An illustrative handbook on nature-like fishways - summarized version. American rivers. Washington , DC. 21pp
24. JACOBSON, R. & PARASIEWICZ, P. (2002): Methods for Defining Instream Flow Standards: New developments in habitat modeling. In proceedings of Connecticut Instream Flow Conference. Berlin, CT March 23, 2001, p. 99 – 113. Yale University.
25. NESTLER, J , P. PARASIEWICZ, N. L. POFF, AND Z. BOWEN (2002). First principles based attributes for describing a template to develop the reference river. –"Environmental flows for river systems." International Working Conference on Assessment and Implementation, incorporating the fourth international Ecohydraulic symposium, Cape Town, South Africa. On CD. March 3-8, 2002.
26. MODER K. & P. PARASIEWICZ (1999): Statistical comparison of physical habitat sampling strategies in streams. Proceedings of workshop on correlated data modeling: The estimating function approach, Trieste, Italy, October 22-23, 1999. On CD.
27. PARASIEWICZ P., EBERSTALLER J., WEISS S. & S. SCHMUTZ (1998): Conceptual guidance for nature-like bypass channels, In: M. Jungwirth, S. Schmutz, S. Weiss (eds), Fish Migration and Fish Bypasses, Fishery News Books, Blackwell Science, Oxford. pp. 348-362.
28. EBERSTALLER, HINTERHOFER M. & P. PARASIEWICZ (1998): The effectiveness of two nature-like bypass-channels in aiding the upstream migration of a rhithral fish assemblage, In: M. Jungwirth, S. Schmutz, S. Weiss (eds), Fish Migration and Fish Bypasses, Fishery News Books, Blackwell Science, Oxford. pp. 363-383.

29. PARASIEWICZ P. & S. SCHMUTZ (1997): Integritá ecologica e deflusso minimo vitale. In AGAC Deflusso minimo vitale. Methodi ed esperienze per un corretto utilizzo della risorsa idrica nel rispetto degli usi ambientali del corsi d´aqua. Convegno nazionale.p 159-163.

30. PARASIEWICZ P., S. SCHMUTZ & O. MOOG, (1996): The effects of managed hydropower peaking on the physical habitat, benthos and fish fauna in the Bregenzerach, a nival 6th order river in Austria. Proceedings of 2nd International Symposium on Habitat Hydraulics „Ecohydraulics 2000" in Quebec, Juni 1996, p. A685-A698.

31. PARASIEWICZ P. & S. SCHMUTZ, (1999) Running water ecology research in Austria. Publication of Austrian Network for Environmental Research. Federal Ministry of Science and Transportation, Vienna, Austria, 80 pp.

32. PARASIEWICZ, P. & H. MADER (1991). Ökomorphometrische Flußvermessung und deren Auswertung. Proceedings of Informationstagung Mikroelektronik ME91 Vienna, August 1991, p. 243-249.

33. PARASIEWICZ P., ROGERS J. N., GORTAZAR J., VEZZA P., WIŚNIEWOLSKI W. & C. Comglio. (in review). The MesoHABSIM Simulation Model – development and applications. In Maddock I., Harby A., Kemp P., Wood P. Ecohydraulics: an integrated approach. John Wiley & Sons Ltd.

Scripts and text books

34. PARASIEWICZ P., ROGERS J.N. & J. LEGROS (2008). MesoHABSIM Field Procedures Manual. Northeast Instream Habitat Program, Mount Holyoke College, MA, USA. pp 49.

Abstracts

41. PARASIEWICZ P., WERLE S., JOHNSON L., ROGERS J. & LONGWORTH B. Northeast Instream Habitat Program. Annual Meeting of New England Association of Environmental Biologist, Lake George, NY, March 16-18, 2005.

42. PARASIEWICZ P., EHMANN S., CORP P. & H. KITSON: Fish Habitat Restoration on Stony Clove Stream, NY. 133rd American Fisheries Society Annual Meeting, Quebec City, QC, August 10-14, 2003. PARASIEWICZ P. Restoration planning on Quinebaug River, MA. Fisheries Bioengineering Symposium, 132nd American Fisheries Society Annual Meeting, Baltimore, MD, August 18-22, 2002.

43. PARASIEWICZ P. & S. EHMANN: MesoHABSIM application on the Quinebaug River, MA. Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO July 30- 2, 2001.

44. PARASIEWICZ P., MATTL M. & K. MODER: A study of strategies for sampling of stream habitat. EISORS - Eight International Symposium on Regulated Rivers – Toulouse, France August 17 21, 2000.

45. MODER K. & P. PARASIEWICZ (1999): Statistical comparison of physical habitat sampling strategies in streams. Workshop on correlated data modeling: The estimating function approach, Trieste, Italy, October, 22-23, 1999. On CD.

46. GRASSER U., PARASIEWICZ P., SCHMUTZ S., JUNGWIRTH M., MOOG O. & S. MUHAR. Assessment of ecological integrity in minimum flow studies. The Austrian approach. International conference on ”Assessing the ecological integrity of running waters”, Vienna, Austria November 9-11, 1998.

47. PARASIEWICZ P., HÖGLINGER B. & H. C. HOFMANN. Der DVP - Stab, Jahrestagung der Deutschen Gesellschaft für Limnologie gem. mit SIL dt. und österr. Sektion, Klagenfurt, September 28 – October 2, 1998.

Technical reports

41. ROGERS J. N., PARASIEWICZ P. & A. ELDRIDGE (2010). A GIS-based application to estimate target fish communities in Northeastern streams. Reports for Northeast Association of Fisheries and Wildlife Agencies. Rushing Rivers Institute, Amherst, MA. pp 128.

42. PARASIEWICZ P. & J. N., ROGERS (2010). Development of a mitigation method and ecological impacts offset for spring water withdrawals on downstream habitats for fish and invertebrates. Report for Nestlé Waters North America. Rushing Rivers Institute, Amherst, MA. pp 335

43. PARASIEWICZ P., THOMPSON D., WALDEN D., ROGERS J.N. & R. HARRIS (2010). Saugatuck River Watershed Environmental Flow Recommendations. Report for The Nature Conservancy and Aquarion. Rushing Rivers Institute, Amherst, MA. pp 678.

44. PARASIEWICZ P., ROGERS J., LARSON A., BALLESTERRO T., CARBONEAU L., LEGROS J. & J. JACOBS. (2008), Lamprey River Protected Instream Flow Report. Report for New Hampshire Department of Environmental Services. NHDES-R-WD-08-26, Concord, NH. pp 980.

45. PARASIEWICZ P., ROGERS J., LEGROS J. & M. WIRTH. (2007). Assessment and restoration of instream habitat of the Eightmile River in Connecticut – Developing MesoHABSIM model. The National Park Service, Wild and Scenic River Study for the Eightmile River and the Eightmile River Wild and Scenic Study Committee. pp 62.

46. PARASIEWICZ P., LEGROS J., ROGERS J. & M. WIRTH. (2007). Assessment and restoration of instream habitat for the Pomperaug, Nonnewaug and Weekeepeemee Rivers of Connecticut. Report for Pomperaug Watershed Coalition. Northeast Instream Habitat Program. University of Massachusetts, Amherst. pp 103.

47. PARASIEWICZ P., MACBROOM J., AHLFELD D., COMPTON B., JACKSON S., MAS D., WIRTH M., & J. LEGROS (2007). Advocate Dam Removal Feasibility Study, Mill River, Hatfield, Massachusetts. Northeast Instream Habitat Program. University of Massachusetts, Amherst. pp. 88. (BALLESTERRO T., KRETCHMAR D., CARBONEAU L., PARASIEWICZ P., LEGROS J., ROGERS J., STEGER T. & J. JACOBS. (2006), Souhegan River Protected Instream Flow Report, NHDES- R-WD-06-50, Concord, NH. Report for New Hampshire Department of Environmental Services.

48. WARNER G. S., OGDEN F. L., BAGTZOGLOU A. C. & P. PARASIEWICZ, (2006) Long-Term Impact Analysis of the University of Connecticut's Fenton River Water Supply Wells on the Habitat of the Fenton River. Report for State of Connecticut, Office of Policy and Management. 211pp.

49. WALDEN, D. L. & P. PARASIEWICZ (2005). Integrative Assessment of Biological and Physical Attributes of the Eightmile River. Report for National Park Service, CT pp 116.

50. BRAWLEY, H. & P. PARASIEWICZ (2005). Developing Target Fish Communities for The Pomperaug Watershed. Report for Pomperaug River Watershed Coalition. pp 13.

51. PARASIEWICZ P. (2005). Ecohydrology study of the Quinebaug River – Final Report for New England Interstate Water Pollution Control Commission. Ithaca, NY. pp 385.

52. PARASIEWICZ P., EHMANN, S. B. & P. CORP (2003). Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM. Report for New York City Department of Environmental Protection and Green County Soil and Water Conservation District and New York State Water Resources Institute. pp 410.

53. PARASIEWICZ P., KITSON H., SNOPKOSKI L., JACKSON S. & S. DESTEFANO (2003). Measuring ecosystem health in western Massachusetts – The Mill River, Hatfield, MA. Report for The Nature Conservancy and Massachusetts Environmental Trust. Ithaca, NY. pp 146.

54. PARASIEWICZ P., KITSON H. & L. SNOPKOSKI (2003) Instream Flow Requirements of Mill River – Hatfield, MA. Report on Phase I: Dwarf Wedge Mussel Habitat Report for Massachusetts Executive Office of Environmental Affairs. Massachusetts Department of Environmental Management, Ithaca, NY. pp 84.

55. PARASIEWICZ P. (2002) Review of Nature-like bypass channels. Report for Natural Resources Council of Maine, Ithaca, NY. pp 30.

56. PARASIEWICZ P. & A. GALLAGHER (2002). Ecohydrology Study of Quinebaug River – Interim Report. NY Cooperative Fish and Wildlife Research Unit and Department of Natural Resources, Cornell University. Project Report

for New England Interstate Water Pollution Control Commission. Ithaca, NY. 125 pp.

57. PARASIEWICZ P. (2001): Strategy for Sustainable Management of the Upper Delaware River Basin. Trout Unlimited. NY. pp 21.

58. PARASIEWICZ P. & S. SCHMUTZ (1999): Biotische Habitatmodellierung. Habitatpotential der Traisen bei unterschiedlichen Struktur- und Abflußverhältnissen. [Habitat modelling as a tool for the development of a river restoration concept at the Traisen River] AP 19b. Gewässerbetreuungskonzept Traisen., HFA-BOKU & DonauConsult. Studie im Auftrag des BMLF, pp 79.

59. PARASIEWICZ P. & SCHMUTZ S. (1998): Gewässerbetreuungskonzept Traisen: Arbeitspaket 14: Istbestandsaufnahme- Detailmorphologie, Project report for Authorities of the Government of Lower Austria - Bundeswasserbauverwaltung, pp 244.

60. GRASSER U., PARASIEWICZ P., PARTHL G. A. & S. SCHMUTZ, (1998) Limnologische Gesammtbeurteilung des KW Alberschwende - Synthesis – Report for Hydroelectric Company of Vorarlberg, pp 23.

61. PARASIEWICZ P., (1997): Morphometrisch/hydraulische & fischökologische Nachuntersuchung des KW Alberschwende Bregenzerach, Fachbereich Morphologie/Hydraulik – Report for Hydroelectric Company of Vorarlberg, pp 174.

62. PARASIEWICZ P., SCHMUTZ S. & G. PARTHL, (1997): Morphometrisch/hydraulische & fischökologische Nachuntersuchung des KW Alberschwende Bregenzerach, Fachbereich Habitatuntersuchung – Report for Hydroelectric Company of Vorarlberg, pp 51.

63. SCHMUTZ S, KAUFMANN M. & P. PARASIEWICZ (1995): Fischökologische und hydraulisch/morphologische Nachuntersuchung der Wagrainer Ache, Expertise for Hydroelectric Company of Upper Austria, pp 159.

64. JUNGWIRTH M., PARASIEWICZ P., HINTERHOFER M., MATITZ A., MEISS C., PARTL P. & W. STEINBERGER (1994): Vergleichende Untersuchung des Fischaufstieges an drei Fischaufstiegshilfe im Rhithralbereich.- Wasserwirtschaftskataster, Study report for Austrian Federal Ministry of Agriculture and Forestry, pp 245.

65. EBERSTALLER J., JUNGWIRTH M. & P. PARASIEWICZ (1994): Fischaufstiegshilfe bei der Wehranlage des KW Weitenegg I und II - Construction planning for H.M. Habicher AG Weitenegg. pp 15.

66. PARASIEWICZ, P., (1992): Fischaufstiegshilfe an der Leitha /Trautmanssdorf, Expertise for Authorities of the Government of Lower Austria. pp 15.

67. PARASIEWICZ P. & R. TESAR, (1992): Fischaufstiegshilfen an der Schwechat /Achau, Experise for Authorities of the Government of Lower Austria. pp 32.

68. JUNGWIRTH M., KAUFMANN T., RADERBAUER J., RATHSCHÜLER O. & P. PARASIEWICZ, (1990): Fischereibiologische Untersuchung der Osterach.- Expertise for Bavarian Office for Watermanagement. pp 46. JUNGWIRTH M., PARASIEWICZ P. & S. SCHMUTZ, (1989): Gutachten über die fischökologischen und fischereiwirtschaftlichen Auswirkungen des Schwellbetriebes des KW Riegler, Kleine Erlauf, Randegg, Expertise for Austrian Fisheries Society. pp 15.

Other publications

WIKIPEDIA: Piotr Parasiewicz, Biography

http://en.wikipedia.org/wiki/Piotr_Parasiewicz

Umass Extension: Extension Highlights Going with the Flow

http://www.umassextension.org/index.php/news-events?start=22

Computer programs

PARASIEWICZ P., E. HAMMOND, J. XU & D. IVANOV (2006) Sim-Stream Software

PARASIEWICZ P. (1993): Morpha – CAD software for river morphological surveys

PARASIEWICZ P. (1993): New Wave – 1D Hydrodynamic Simulation model for streams.

Magazine articles

PARASIEWICZ P. (2010) Book review: Integrated Approaches to Riverine Resource Stewardship. Fisheries (in print).

PARASIEWICZ P., (1998) Zadania gospodarki rzecznej w Polsce w perspektywie wstapienia do Unii Europejskiej. Środowisko, 12/98: 32-34 (reprinted in Aura and Gospodarka Wodna 1999).

On-line publications

WILDMAN L, P. PARASIEWICZ, C. KATOPODIS, U. DUMONT 2003. An illustrative handbook on nature-like fishways - summarized version. American rivers. http://act.americanrivers.org/site/DocServer/Nature-LikeFishwaysHandbook.pdf?docID=202

PARASIEWICZ P. & C. PARASIEWICZ, (2009): MeosoHABSIM www.MesoHABSIM.org

PARASIEWICZ P. & C. PARASIEWICZ, (2008): Rushing Rivers Institute www.RushingRivers.org

PARASIEWICZ P., C. PARASIEWICZ, M. LICIS, J. ABDOW, A.DEIANA (2008): River Climate Action: www.RiverClimate.org

Government publications

PARASIEWICZ P. & S. SCHMUTZ, (1999) Running water ecology research in Austria. Publication of Austrian Network for Environmental Research. Federal Ministry of Science and Transportation, Vienna, Austria, 80 pp.

Posters

PARASIEWICZ, P., WERLE, S., JOHNSON, L., ROGERS J. & LONGWORTH B. Northeast Instream Habitat Program. Annual Meeting of New England Association of Environmental Biologist, Lake George, NY, 3/16-18/2005.

PARASIEWICZ, P., EHMANN, S., P. CORP & H. KITSON: Fish Habitat Restoration on Stony Clove Stream, NY. 133rd American Fisheries Society Annual Meeting, Quebec City, QC, 8/10-8/14/2003.

PARASIEWICZ, P. Restoration planning on Quinebaug River, MA. Fisheries Bioengineering Symposium, 132nd American Fisheries Society Annual Meeting, Baltimore, MD, 8/18-8/22/2002.

PARASIEWICZ, P. & S. EHMANN: MesoHABSIM application on the Quinebaug River, MA. Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO 7/30-8/2/2001

PARASIEWICZ, P., MATTL, M. & K. MODER: A study of strategies for sampling of stream habitat. EISORS - Eight International Symposium on Regulated Rivers – Toulouse, France 8/17 – 8/21/2000.

MODER K. & P. PARASIEWICZ (1999): Statistical comparison of physical habitat sampling strategies in streams. Workshop on correlated data modeling: The estimating function approach, Trieste, Italy, 22-23 .10. 1999.

GRASSER U., PARASIEWICZ P., SCHMUTZ S., JUNGWIRTH M., MOOG O. & MUHAR S.(1998): Assessment of ecological integrity in minimum flow studies. The Austrian approach. International conference on "Assessing the ecological integrity of running waters", Vienna, Austria 9.-11.11.1998

PARASIEWICZ P., HÖGLINGER B. & H. C. HOFMANN (1998): Der DVP - Stab Poster, Jahrestagung der Deutschen Gesellschaft für Limnologie gem. mit SIL dt. und österr. Sektion, Klagenfurt, 28.9.-2.10.1998.

Presentations

2010

1. PARASIEWICZ P & J. N. ROGERS. Dwarf Wedgemussel Habitat Study on the Upper Delaware River Annual meeting of American Fisheries Society. Pittsburgh, September 10-16, 2010.

2. PARASIEWICZ P. Application of MesoHASBIM approach. New Zealand Regional Council of Governments, Napier, NZ, March 11-12, 2010.

2009

3. PARASIEWICZ P. Application of MesoHABSIM. ETH Zurich. Kastanienbaum, Switzerland. October 30, 2009.
4. PARASIEWICZ P. Use of the Mesohabitat Simulation Model (MesoHABSIM) for Instream Habitat Assessments, EPFL Lausanne, Lausanne, Switzerland. October 29, 2009.
5. PARASIEWICZ P. Application of MesoHABSIM model and habitat time series analysis for flow management and river restoration. University of Montreal. Montreal, Canada. January 25, 2009.
6. PARASIEWICZ P., SEAGER T., T.MEYER, E. EDELSON. Actogram and Habitat Meter: tools for real time assessment of the fish habitat status in streams. Ecohydraulics 2009 Concepcion, Chile, January 12-16, 2009

2008

7. PARASIEWICZ P., T. SEAGER, MEYER T., EDELSON E.. Actogram and Habitat Meter: tools for real time assessment of the fish habitat status in streams. Annual meeting of American Fisheries Society. Ottawa, August17-21, 2008.

2006

8. PARASIEWICZ, P., ROGERS J.N & J. LEGROS. Habitat restoration through habitat structure and instream flows dynamics for the Pomperaug River in Connecticut. 136th American Fisheries Society Annual Meeting, San Francisco, CA, August 10-14, 2006.

2005

9. PARASIEWICZ P. Contemporary techniques in River management. Polish Ministry of Industrial Development. Warsaw, Poland May 22, 2005.
10. PARASIEWICZ P. Northeast Instream Habitat Program. European Commission. European Aquatic Modelling Network. Final conference of COST Action 626 in Silkeborg, Denmark May 19-20, 2005.
11. PARASIEWICZ P. MesoHABSIM Model "Connecting science to Application". NOAA Restoration Center. April 13, 2005.
12. PARASIEWICZ, P., BALLESTERO, T.& KRETCHMER D. Instream flow studies and watershed management plan for the Souheagan River Designated Reach. University Council of Water Resources and National Institute of Water Resources 2005 Conference: Lake and River Restoration: Changing Landscapes Portland, ME July 12-14, 2005.

13. PARASIEWICZ, P. Northeast Instream Habitat Program European Aquatic Modelling Network. Final conference of COST Action 626 in Silkeborg, Denmark May 19-20, 2005.

14. PARASIEWICZ P. WALDEN D. & S.F. WERLE. Biological and Physical Status Assessment of the Eightmile River – A Component of the Wild and Scenic River Study. Annual Meeting of New England Association of Environmental Biologist, Lake George, NY March 16-18, 2005.

2004

15. FENNESSEY, N.M., P. PARASIEWICZ & M.T. GOETTEL, Assessment of Alternative Streamflow Augmentation Schemes for the Restoration of the Quinebaug River Watershed, Proceedings of the World Water and Environmental Resources Congress 2004, ASCE, Salt Lake City, UT, June 27-July 1, 2004.

16. PARASIEWICZ P. Assessing and Visualizing Mesoscale Ecological Flow Requirements. Second Annual MA WRRC Conference:Water Resources in the Northeast: Emerging Issues Amherst, MA. October 22, 2004.

17. PARASIEWICZ P., NESTLER, J., POFF N. L. & M. B. BAIN: Virtual Reference River – a model of reference habitat conditions. MA. Annual Meeting of New England Association of Environmental Biologist, Jiminy Peak, MA, March 26-28, 2004.

2003

18. PARASIEWICZ P., FENNESSEY N. & M GOETTEL, Defining measures to reduce fish habitat degradation in the Quinebaug River, New England. 133rd American Fisheries Society Annual Meeting, Quebec City, QC, August 10-14, 2003.

19. PARASIEWICZ P., FENNESSEY N. & M. GOETTEL: Defining measures to reduce fish habitat degradation in the Quinebaug River, New England. 133rd American Fisheries Society Annual Meeting, Quebec City, QC, August 10-14, 2003.

20. PARASIEWICZ P., EHMANN, S., P. Corp & H. Kitson: Fish Habitat Restoration on Stony Clove Stream, NY. 133rd American Fisheries Society Annual Meeting, Quebec City, QC, August 10-14, 2003.

21. PARASIEWICZ, P.: Site-Specific Case Study, Part II: Quinebaug River, MA. Annual Meeting of New England Association of Environmental Biologist, Wachusett, MA, March 26-28, 2003.

22. PARASIEWICZ P.: Upscaling: Integrating habitat model into river management. International workshop on “State of the art in habitat modeling and conservation flows”, Quebec City, Canada, March 4 -5, 2003.

2002

23. JACOBSON, R. & PARASIEWICZ, P. (2002): Methods for Defining Instream Flow Standards: New developments in habitat modeling. In proceedings of Connecticut Instream Flow Conference. Berlin, CT March 23, 2001, p. 99 – 113. Yale University.

24. NESTLER, J , P. PARASIEWICZ, N. L. POFF, & Z. BOWEN (2002). First principles based attributes for describing a template to develop the reference river. Proceedings of environmental flows for river systems." International Working Conference on Assessment and Implementation, incorporating the fourth international Ecohydraulic symposium, Cape Town, South Africa, March 3-8, 2002.

25. PARASIEWICZ P., N., GILLESPIE, D. SHEPPARD, M. T. WALTER (2002). Defining environmental flows for Upper Delaware River. Delaware River Symposium, 132nd American Fisheries Society Annual Meeting, Baltimore, MD, August 18-22, 2002.

26. PARASIEWICZ P., NESTLER, J., POFF, N. L. & Z. BOWEN (2002) Virtual Reference River – a model of reference habitat conditions. Bioengineering Symposium, 132nd American Fisheries Society Annual Meeting, Baltimore, MD, August 18-22, 2002.

27. WILDMAN, L., P. PARASIEWICZ, C. KATOPODIS, U.DUMONT (2002) An Illustrative Handbook on Nature-Like Fishways - Summarized Version. Bioengineering Symposium, 132nd American Fisheries Society Annual Meeting, Baltimore, MD, August 18-22, 2002.

28. PARASIEWICZ P. Northeast Instream Habitat Program. Northeast Fish and Wildlife Conference. Portland, ME, April 23-21, 2002.

29. NESTLER, J , P. PARASIEWICZ, N. L. POFF, and Z. BOWEN. First principles based attributes for describing a template to develop the reference river. – "Environmental flows for river systems." International Working Conference on Assessment and Implementation, incorporating the fourth international Ecohydraulic symposium, Cape Town, South Africa. March 3-8, 2002.

2001

30. PARASIEWICZ P. Northeast Instream Habitat Program, European Science Foundation. COST Action 626 "European Aquatic Modelling Network", Trondheim, Norway, 5/11-12/2001.

31. PARASIEWICZ P. MesoHABSIM habitat model. University of Oslo, Norway. Zoological Museum of University of Oslo, Oslo, Norway. May 8, 2001.

32. PARASIEWICZ, P. How pristine is Beaver Kill River? Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO 7/30-8/2/2001.

33. PARASIEWICZ, P. & S. EHMANN: MesoHABSIM application on the Quinebaug River, MA. Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO 7/30-8/2/2001.

34. PARASIEWICZ P. (2001): MesoHABSIM application on the Quinebaug River – the success story. 57th Northeast Fish and Wildlife Conference, Saratoga Springs, NY, 4/22-25/2001.

35. PARASIEWICZ, P. & S. EHEMANN (2001): MesoHABSIM application on the Quinebaug River, MA. Managing the flows for biodiversity – A conference on science, policy and conservation action. Colorado State University. Fort Collins, CO 7/30-8/2/2001.

36. PARASIEWICZ P. (2001): New developments in habitat modeling. Connecticut Instream Flow Conference held by River Alliance and University of Yale. Berlin, CT 3/23/2001.

2000

37. PARASIEWICZ P. (2000): Nature-like bypass channels – a concept for construction and planning. Workshop by US Army Corps of Engineers "Passage for Non-Salmonid Fishes in Streams and Rivers: A Critical Element in Ecosystem Management and Restoration", Wilmington, NC, April 2000.

38. PARASIEWICZ P. & M. B. BAIN (2000): MesoHABSIM or modeling of physical habitat at the scale relevant to river restoration planning. EISORS - Eight International Symposium on Regulated Rivers – Toulouse, France 8/17 – 8/21/2000.

39. PARASIEWICZ, P., MATTL, M. & K. MODER (2000): A study of strategies for sampling of stream habitat. EISORS - Eight International Symposium on Regulated Rivers – Toulouse, France 8/17 – 8/21/2000.

1999

40. MODER K. & P. PARASIEWICZ (1999): Statistical comparison of physical habitat sampling strategies in streams. Proceedings of workshop on correlated data modeling: The estimating function approach, Trieste, Italy, 22-23 October 1999.

41. SCHMUTZ, S. & P. PARASIEWICZ (1999): Wasserkraft und Fischfauna – Bewertung und Modelle. Proceedings of International Symposium „Problemkreis Pflichtwasserabgabe – Ökologisch begründete Mindestabflüsse in Ausleitungsstrecken von Wasserkraftwerken". 21-23. Juni 1999, Brauhaus Puntigam, Graz.

42. PARASIEWICZ, P., MATTL, M. & K. MODER (1999): A study of effectiveness of alternative physical habitat sampling strategies in streams. Proceedings of 3rd international symposium on ecohydraulics. Salt Lake City, Utah, USA, July 1999.

1998

43. PARASIEWICZ P., (1998): Long- and midterm measures for flood protection in Poland – basic Requirements. Proceedings of EUREKA international conference "Water Source of Life source of danger" in Cracow, March 1998.

44. PARASIEWICZ, P. & M. DUNBAR (1998) : Physical habitat modelling - a developing approach. Invited key note address, International Workshop : 0+ fish as indicators of the ecological status of rivers, University of Vienna. 16.-20.2.1998.

45. GRASSER U., PARASIEWICZ P., SCHMUTZ S., JUNGWIRTH M., MOOG O. & S. MUHAR (1998): Assessment of ecological integrity in minimum flow studies. The Austrian approach. International conference on ”Assessing the ecological integrity of running waters”, Vienna, Austria 9.-11.11.1998.

46. PARASIEWICZ P., HARBY A., LE COARER Y., MADER H. & M. MATTL (1998): Spatial sampling strategies in streams – accuracy and compatibility concerns. VII International Congress of Ecology: Spatial processes and scaling: Merging field data collection methods and modelling. 19-25. 7. 1998, Florence.

47. PARASIEWICZ P., HÖGLINGER B. & H. C. HOFMANN (1998): Der DVP - Stab Poster, Jahrestagung der Deutschen Gesellschaft für Limnologie gem. mit SIL dt. und österr. Sektion, Klagenfurt, 28.9.-2.10.1998.

1997

48. PARASIEWICZ P., HOFMANN H. C. & B. HÖGLINGER (1997): The DVP - Depth Velocity Position Bar - a multiplex instrument for physical habitat measurements in small riverine domains – SISSORS III – Seventh International Symposium on Regulated Streams in Chattanooga, Tennesseee, USA, 25-29 August 1997.

49. PARASIEWICZ, P., S., SCHMUTZ & O. MOOG (1997): The biological evaluation of minimum flow and hydro-peaking management plan on two Austrian rivers. - SISSORS III – Seventh International Symposium on Regulated Streams in Chattanooga, Tennessee 25-29 August 1997.

50. PARASIEWICZ P. & C. P. GUBALA (1997): International Aquatic Modelling Group – activities report – American Fisheries Society 127th Annual Meeting, Monterey, California – 24-28 August 1997.

1996

51. PARASIEWICZ P., S. SCHMUTZ & O. MOOG, (1996): The effects of managed hydropower peaking on the physical habitat, benthos and fish fauna in the Bregenzerach, a nival 6th order river in Austria. International Symposium on Habitat Hydraulics „Ecohydraulics 2000“ in Quebec, June1996.

Interviews

Kraft S. (2009): Quiet on the River, The Valley Advocate, Northampton, MA, 2/19/2009 http://www.valleyadvocate.com/article.cfm?aid=9240

Palpini K. (2007): Trouble signs in the river: Researchers eye missing shiners. Hampshire Gazette, http://www.oceanriver.org/documents/Troublesigns_in_the_river_Researchers.pdf

WFCR Public Radio (2003) Surveying River water flow. Morning edition: Field notes. Amherst, MA.

WCNY Public TV (2003): Onondaga Creek Restoration on Hours WCNY. Syracuse, NY.

Russell, G. (2000): A River of doubt. Power plant plan generates myriad fears for Quinebaug. Telegram & Gazette, Worcester, MA, 8/27/2000.

Forowicz, K. (1998): Piękne, ale brudne. Rzeczpospolita (Polish national government newspaper). Warsaw, Poland, 8/25/1998.

Resume

Dr. MARVIN RESNIKOFF is an international consultant on radioactive waste issues. A nuclear physicist and a graduate of the University of Michigan, Dr. Resnikoff has worked on radioactive issues since his first project at West Valley, New York in 1974. Throughout his career, he has assisted public interest groups and state and local governments across the US in order to identify and create solutions for radioactive waste storage and transportation issues. His recent research focus has been on the risk of transporting and storing radioactive waste and the health impact of radioactive waste from oil and uranium production. Dr. Resnikoff has also co-authored four books on radioactive issues, including *Deadly Defense* and *Danger Below*, both regarding contamination at DOE facilities. In June 2000, he was appointed by DOE secretary Bill Richardson to a Blue Ribbon Panel on Alternatives to Incineration. In August 2010, he was an invited panelist to President Obama's Blue Ribbon Commission on Nuclear Safety. In October 2011, he was an invited panelist at the annual conference of the Water Environment Federation on the subject of radioactivity in Marcellus shale wastes. In November 2013, he was an invited panelist before the Nuclear Waste Technical Review Board on the subject of the implication of high burnup nuclear fuel on decommissioning and transportation.

Since 1992, he has researched NORM issues, continuing to serve as an expert witness in personal injury cases in Mississippi, Louisiana and Texas on behalf of workers injured while cleaning radium-contaminated oil pipes. In 2009, he served as an expert witness for a Texas rancher whose land was contaminated by natural gas operations. He also served as an expert witness for public interest groups concerned with Marcellus shale rock cuttings going to the Chemung County, New York solid waste landfill. In 2012, he prepared a report for public interest groups on the NORM situation in Ohio. He is presently preparing a report on the impact of natural gas exploration and production in Pennsylvania.

He has conducted studies on the remediation and closure of the leaking Maxey Flats, Kentucky radioactive landfill for Maxey Flats Concerned Citizens, Inc. and of the leaking uranium basin on the NMI/Starmet site in Concord, Massachusetts under grants from the Environmental Protection Agency. He co-authored a study on the cost of remediating the former West Valley, New York reprocessing plant site. He also conducted studies of the Wayne and Maywood, New Jersey thorium Superfund sites and proposed low-level radioactive waste facilities at Martinsville (Illinois), Boyd County (Nebraska), Wake County (North Carolina), Ward Valley (California) and Hudspeth and Andrews Counties (Texas). He investigated phosphogypsum plants in Florida, Texas and Alberta, Canada, and served as an expert witness in a personal injury case involving a Texas phosphogypsum worker. He also served as an expert witness for CRPE, a public interest group, regarding the proposed expansion of the Buttonwillow, California NORM landfill. He was an expert witness for Earthjustice re. the licensing of an irradiation facility near the Honolulu airport in Hawaii. He is serving as an expert witness for Niagara County, New York, in a licensing hearing re. an application by CWM to expand its hazardous waste landfill.

RADIOACTIVE WASTE MANAGEMENT ASSOCIATES

Marvin Resnikoff, Ph.D.
Curriculum Vitae

EDUCATION:

Ph.D., Physics	1965, University of Michigan
M.S., Physics	1962, University of Michigan
B.A., Physics/Math	1959, University of Michigan

SUMMARY OF PROFESSIONAL EXPERIENCE:

Marvin Resnikoff is Senior Associate at Radioactive Waste Management Associates and is an international consultant on radioactive waste management issues. He is Principal Manager at Associates and is Project Director for dose reconstruction and risk assessment studies of radioactive waste facilities and transportation of radioactive materials. Dr. Resnikoff has concentrated exclusively on radioactive waste issues since 1974. He has authored or co-authored four books on radioactive waste issues.

He has conducted dose reconstruction studies of oil pipe cleaners in Mississippi and Louisiana, residents of Canon City, Colorado near a former uranium mill, residents of West Chicago, Illinois near a former thorium processing plant, and residents and former workers at a thorium processing facility in Maywood, New Jersey. He has also served as an expert witness for plaintiffs in Karnes County, Texas, Milan, New Mexico and Uravan, Colorado, who were exposed to radioactivity from uranium mining and milling activities. He is continuing to work on personal injury cases involving former workers and residents at the ITCO and other oil pipe cleaning yards in Louisiana and Texas. He also evaluated radiation exposures and risks in worker compensation cases involving former workers at Maywood Chemical Works thorium processing plant. He also served as an expert witness in a case involving the Port St. Lucie reactors and brain cancer developed by two children and in a case involving clean-up of an abandoned radioactive materials processing facility in Webster, Texas. He is presently working on several land contamination cases in Louisiana, Texas and New York. In June 2000, he was appointed to a Blue Ribbon Panel on Alternatives to Incineration by DOE Secretary Bill Richardson.

In addition to dose reconstruction and land contamination cases, Dr. Resnikoff also works on the risk of transporting radioactive material. Under a contract with the State of Utah, Dr. Resnikoff was a technical consultant to DEQ on the proposed dry cask storage facility for high-level waste at Skull Valley, Utah. He assisted the State on licensing proceedings before the Nuclear Regulatory Commission. He has also prepared studies on transportation risks and consequences for the State of Nevada and the Nevada counties: Clark, White Pine, Lander and Churchill. In addition, at hearings before state commissions and in federal court, he investigated proposed dry storage facilities at the Point Beach (WI), Prairie Island (MN), Palisades (MI), Maine Yankee, Connecticut Yankee and Vermont Yankee reactors. He is presently working for the State of Nevada on Yucca Mountain repository issues before the Nuclear Regulatory Commission (NRC). He is also serving as an expert witness for Earthjustice on a proposed NRC license for a food irradiator at the Honolulu, Hawaii airport.

He has conducted studies on the remediation and closure of the leaking Maxey Flats, Kentucky radioactive landfill for Maxey Flats Concerned Citizens, Inc. and of the leaking uranium basin on the NMI/Starmet site in Concord, Massachusetts under grants from the Environmental Protection Agency. He co-authored a study on the cost of remediating the former West Valley, New York reprocessing plant site. He also conducted studies of the Wayne and Maywood, New Jersey thorium Superfund sites and proposed low-level radioactive waste facilities at Martinsville (Illinois), Boyd County (Nebraska), Wake County (North Carolina), Ward Valley (California) and Hudspeth County (Texas). He investigated phosphogypsum plants in Florida, Texas and Alberta, Canada, and served as an expert witness in a personal injury case involving a Texas phosphogypsum worker. He also served as an expert witness for CRPE, a public interest groups, regarding the proposed expansion of the Buttonwillow, California NORM landfill. He is presently working for Earthjustice re. the licensing of an irradiation facility near the Honolulu airport in Hawaii.

In Canada, he conducted studies on behalf of the Coalition of Environmental Groups and Northwatch for hearings before the Ontario Environmental Assessment Board on issues involving radioactive waste in the nuclear fuel cycle and Elliot Lake tailings and the Interchurch Uranium Coalition in Environmental Impact Statement hearings before a Federal panel regarding the environmental impact of uranium mining in Northern Saskatchewan. He also worked on behalf of the Morningside Heights Consortium regarding radium-contaminated soil in Malvern and on behalf of Northwatch regarding decommissioning the Elliot Lake tailings area before a FEARO panel. He conducted a study for Concerned Citizens of Manitoba regarding transportation of irradiated fuel to a Canadian high-level waste repository. He is presently working for Greenpeace reviewing the environmental assessment for a proposed intermediate level waste repository under Lake Huron, and for the Provincial Womens Council of Ontario on radioactive waste management costs in a proceeding before the Ontario Energy Board.

In February 1976, assisted by four engineering students at State University of New York at Buffalo, Dr. Resnikoff authored a paper that, according to *Science*, changed the direction of power reactor decommissioning in the United States. His paper showed that power reactors could not be entombed for long enough periods to allow the radioactivity to decay to safe enough levels for unrestricted release. The presence of long-lived radionuclides meant that large volumes of decommissioning waste would still have to go to low-level or high-level waste disposal facilities. He assisted public interest groups on the decommissioning of the Yankee-Rowe, Diablo Canyon, Big Rock Point and Haddam Neck reactors.

He was formerly Research Director of the Radioactive Waste Campaign, a public interest organization conducting research and public education on the radioactive waste issue. His duties with the Campaign included directing the research program on low-level commercial and military waste and irradiated nuclear fuel transportation, writing articles, fact sheets and reports, formulating policy and networking with numerous environmental and public interest organizations and the media. He is author of the Campaign's book on "low-level" waste, *Living Without Landfills*, and co-author of the Campaign's book, *Deadly Defense, A Citizen Guide to Military Landfills*.

Between 1981 and 1983, Dr. Resnikoff was a Project Director at the Council on Economic Priorities, a New York-based non-profit research organization, where he authored the 390-page study, *The Next Nuclear Gamble, Transportation and Storage of Nuclear Waste*. The CEP study details the hazard of transporting irradiated nuclear fuel and outlines safer options.

Dr. Resnikoff is an international expert in nuclear waste management, and has testified often before State Legislatures and the U.S. Congress. He has extensively investigated the safety of the West Valley, New York and Barnwell, South Carolina nuclear fuel reprocessing facilities. His paper on reprocessing economics (Environment, July/August, 1975) was the first to show the marginal economics of recycling plutonium. He completed a more detailed study on the same subject for the Environmental Protection Agency, "Cost/Benefits of U/Pu Recycle," in 1983. His paper on decommissioning nuclear reactors (Environment, December, 1976) was the first to show that reactors would remain radioactive for several hundred thousand years. In March 2004, Dr. Resnikoff was project director and co-author of a study of groundwater contamination at DOE facilities, Danger Lurks Below.

Dr. Resnikoff has prepared reports on incineration of radioactive materials, transportation of irradiated fuel and plutonium, reprocessing, and management of low-level radioactive waste. He has served as an expert witness in state and federal court cases and agency proceedings. He has served as a consultant to the State of Kansas on low-level waste management, to the Town of Wayne, New Jersey, in reviewing the cleanup of a local thorium waste dump, to WARD on disposal of radium wastes in Vernon, New Jersey, to the Southwest Research and Information Center and New Mexico Attorney General on shipments of plutonium-contaminated waste to the WIPP facility in New Mexico and the State of Utah on nuclear fuel transport. He has served as a consultant to the New York Attorney General on air shipments of plutonium through New York's Kennedy Airport, and transport of irradiated fuel through New York City, and to the Illinois Attorney General on the expansion of the spent fuel pools at the Morris Operation and the Zion reactor, to the Idaho Attorney General on the transportation of irradiated submarine fuel to the INEL facility in Idaho and to the Alaska Attorney General on shipments of plutonium through Alaska. He was an invited speaker at the 1976 Canadian meeting of the American Nuclear Society to discuss the risk of transporting plutonium by air. As part of an international team of experts for the State of Lower Saxony, the Gorleben International Review, he reviewed the plans of the nuclear industry to locate a reprocessing and waste disposal operation at Gorleben, West Germany. He presented evidence at the Sizewell B Inquiry on behalf of the Town and Country Planning Association (England) on transporting nuclear fuel through London. In July and August 1989, he was an invited guest of Japanese public interest groups, Fishermen's Cooperatives and the Japanese Congress Against A- and H- Bombs (Gensuikin).

Between 1974 and 1981, he was a lecturer at Rachel Carson College, an undergraduate environmental studies division of the State University of New York at Buffalo, where he taught energy and environmental courses. The years 1975-1977 he also worked for the New York Public Interest Group (NYPIRG).

In 1973, Dr. Resnikoff was a Fulbright lecturer in particle physics at the Universidad de Chile in Santiago, Chile. From 1967 to 1973, he was an Assistant Professor of Physics at the State University of New York at Buffalo. He has written numerous papers in particle physics, under grants from the National Science Foundation. He is a 1965 graduate of the University of Michigan with a Doctor of Philosophy in Theoretical Physics, specializing in group theory and particle physics. Dr. Resnikoff is a member of the American Public Health Association and the Health Physics Society.

PROFESSIONAL EXPERIENCE:

April 1989 - present **Senior Associate**, Radioactive Waste Management Associates, management of consulting firm focused on radioactive waste issues, evaluation of nuclear transportation and military and commercial radioactive waste disposal facilities.

1978 - 1981; 1983 - April 1989 **Research Director**, Radioactive Waste Campaign, directed research program for Campaign, including research for all fact sheets and the two books, *Living Without Landfills*, and *Deadly Defense*. The fact sheets dealt with low-level radioactive waste landfills, incineration of radioactive waste, transportation of high-level waste and decommissioning of nuclear reactors. Responsible for fund-raising, budget preparation and project management.

1981 - 1983 **Project Director**, Council on Economic Priorities, directed project which produced the report *The Next Nuclear Gamble*, on transportation and storage of high-level waste.

1974 - 1981 **Instructor**, Rachel Carson College, State University of New York at Buffalo, taught classes on energy and the environment, and conducted research into the economics of recycling of plutonium from irradiated fuel under a grant from the Environmental Protection Agency.

1975 - 1976 **Project Coordinator**, SUNY at Buffalo, New York Public Interest Research Group, assisted students on research projects, including project on waste from decommissioning nuclear reactor.

1973 **Fulbright Fellowship** at the Universidad de Chile, conducting research in elementary particle physics.

1967 - 1972 **Assistant Professor of Physics**, SUNY at Buffalo, conducted research in elementary particle physics and taught a range of graduate and undergraduate physics courses.

1965 - 1967 **Research Associate**, Department of Physics, University of Maryland, conducted research into elementary particle physics.

PROFESSIONAL ORGANIZATIONS:

Health Physics Society
Water Environment Federation

SPECIAL SPEAKING ENGAGEMENTS:

1967	Invited Speaker, w/ O.W. Greenberg, Meeting of the American Physical Society, Washington, D.C., "Symmetric Quark Model of Baryon Resonances," Conf-670414—6.
1976	Invited Speaker, Meeting of the American Nuclear Society, Toronto, Canada, "Comparison of risk assessments of Pu released during transport."
1976	Statement before the Subcommittee on Energy and the Environment of the Interior Committee, House of Representatives, on recycling of plutonium.
1977	Statement before the Subcommittee on Government Operations, House of Representatives, on Nuclear Power Costs
1979	Chaired panel w/Dr. Karl Morgan and Dr. Alice Stewart, Gorleben International Review, on the health effects of radiation, Hanover, Germany.
2000	Invited day-long seminar presentation to the California Department of Health on the health effects of radiation
2002	Testimony before the Committee on Transportation & Infrastructure, United States House of Representatives, on transportation of nuclear materials.
2003	Presentation before the National Academy of Sciences Study Committee on Transportation of Radioactive Waste, Las Vegas, NV, "Baltimore Tunnel Fire: Implications for SNF Transportation Safety."
2006	Biglin, K. and Resnikoff, M, Emergency Response to a Nuclear Waste Shipment Accident, Inyo County, June 15, 2006, paper presented at ESRI Annual Conference, August 2006.
2008	Invited Speaker, Meeting of the American Nuclear Society, Anaheim, CA, "State of Nevada Recommendations for Yucca Mountain Transportation Safety and Security."
2008	Presentation at Waste Management 2008, Phoenix, AZ, "Fugitive Dust Emissions from Uranium Haul Roads."
2008	Presentation at Waste Management 2008, Phoenix, AZ, "State of Nevada Perspective on the US DOE Yucca Mountain Transportation Program."

Books and Articles

Resnikoff, M, "Expensive Enrichment," *Environment*, July/August 1975, pp. 28–35.

Harwood, S *et al*, “The Cost of Turning It Off,” *Environment*, December 1976, pp.17-26.

M. Resnikoff, “Environmental Perspective.” Chapter 7 in “The Politics of Nuclear Waste,” edited by William Colglazier, Pergamon Press, 1982

M. Resnikoff, *et al*, “The Next Nuclear Gamble, Transportation and Storage of Nuclear Waste,” Council on Economic Priorities, 1983.

M. Resnikoff, “Shipping Flasks in Severe Rail Accidents,” Chapter 18 in “The Urban Transportation of Irradiated Fuel,” edited by John Surrey, Macmillan Press, London, 1984.

M. Resnikoff, “Living Without Landfills,” Radioactive Waste Campaign, 1988.

M. Resnikoff, *et al*, “Deadly Defense, A Citizen Guide to Military Landfills,” Radioactive Waste Campaign, 1989.

M. Marvin Resnikoff, “The Generation Time Bomb: Radioactive and Chemical Wastes.” Chapter in “Hidden Dangers: Environmental Consequences of Preparing for War,” edited by Anne Ehrlich and John Birks, Sierra Club Books, San Francisco, 1990.

I. Fairlie and M. Resnikoff, “No Dose Too Low,” The Bulletin of Atomic Scientists, Nov/Dec 1997.

M. Resnikoff, “Danger Lurks Below,” Alliance for Nuclear Accountability, 2004.

M Resnikoff, “Radon in Natural Gas from Marcellus Shale,” Ethics in Biology, Engineering & Medicine, Vol. 2, Issue 4, 2011, pp. 317- 331.

Matthew Kelso

Manager of Data and Technology
FracTracker Alliance
112 Sherman Street
Pittsburgh, PA 15209

Education
B.A. in Anthropology from Humboldt State University in Arcata, CA (2003, cum laude)
Includes one-year study abroad in Xi'an, China at Xibei Daxue.

Summary of Experience

FracTracker Alliance – Manager of Data and Technology (2012 – current)
In this position, Mr. Kelso performs data analysis and print and online Geographic Information Systems (GIS) for the FracTracker Alliance, and oversees standards of these functions within the organization. Software frequently used includes ArcGIS Desktop, ArcGIS Online, Microsoft Word and Microsoft Excel.

University of Pittsburgh Graduate School of Public Health, Center for Healthy Environments and Communities – Data Manager (2010 to 2012)
FracTracker was a project of the Center for Healthy Environments and Communities through 2012, before becoming its own 501 (c)(3) nonprofit organization. Mr. Kelso performed data analysis and print and online GIS functions in this capacity.

KEYS Service Corps – AmeriCorps Member (2009 to 2010)
Mr. Kelso was an AmeriCorps member, chiefly serving as a classroom assistant at the Propel Montour charter school in Kennedy Township, PA

Various Cultural Resources Management Companies – Archaeologist (2004 to 2008)
Mr. Kelso worked as an archaeologist on numerous projects and for a variety of companies. Duties included excavation and survey, artifact analysis, artifact curation, and report writing. Most projects were in New Mexico, with additional projects in Wyoming, Arizona, and Virginia, and typically lasted between two and eight weeks.

Peer Reviewed Publications

Malone, Samantha, Matthew Kelso, Ted Auch, Karen Edelstein, Kyle Ferrar, and Kirk Jalbert. (2015). "Inconsistencies with Data from Unconventional Gas and Oil Basins," Journal of Environment Science and Health, Part A, 50(5):489-498.

Samantha Malone, Matthew Kelso, Drew Michanowicz, Kyle Ferrar, Kyra Naumoff Shields and Jill Kriesky. ENVIRONMENTAL REVIEWS AND CASE STUDIES: FracTracker Survey and Case Studies: Application for Participatory GIS in Unconventional Natural Gas Development. *Environmental Practice* 14:1–10 (2012). doi:10.1017/S1466046612000324.

White Papers

Kelso, Matthew (2018). "A Hazy Future: Pennsylvania's Energy Landscape in 2045", FracTracker Alliance, white paper for the Heinz Endowments. https://www.fractracker.org/a5ej20sjfwe/wp-content/uploads/2018/01/AHazyFuture-FracTracker-2018.pdf

Web Published Projects

Kelso, Matthew. 2018. "High Impact Areas and Donut Holes - Variability in PA's Unconventional O&G Industry." FracTracker Alliance.
http://ft.maps.arcgis.com/apps/MapJournal/index.html?appid=4703763deb4041f3bf11f889338a1951

The Oil and Gas Threat Map. 2016-2017. Earthworks, FracTracker Alliance, and Clean Air Task Force.
http://oilandgasthreatmap.com/

Kelso, Matthew. 2017. "What is the Life Expectancy of the Marcellus Shale?" FracTracker Alliance.
https://www.fractracker.org/2017/10/life-expectancy-marcellus-shale/

Jalbert, Kirk and Matthew Kelso. 2017. "Susquehanna River Basin Impacts Project," FracTracker Alliance.
https://www.fractracker.org/projects/susquehanna-river-basin-impacts-project/

Kelso, Matthew and Kirk Jalbert. 2016. "Allegheny County Lease Mapping Project." FracTracker Alliance.
https://www.fractracker.org/projects/lease-mapping/

Invited Talks

"Information Forum – Injection Wells" September 21, 2017, Plum Borough, Allegheny County, Pennsylvania. https://www.youtube.com/watch?v=wX9frQvPhSw

Tom Myers, Ph.D.
Consultant, Hydrology and Water Resources
6320 Walnut Creek Road
Reno, NV 89523
(775) 530-1483
Tommyers1872@gmail.com

Curriculum Vitae

Objective: To provide diverse research and consulting services to nonprofit, government, legal and industry clients focusing on hydrogeology specializing in mine dewatering, contaminant transport, natural gas development, groundwater modeling, NEPA analysis, federal and state regulatory review, and fluvial morphology.

Education

Years	Degree	University
1992-96	Ph.D. Hydrology/Hydrogeology	University of Nevada, Reno Dissertation: Stochastic Structure of Rangeland Streams
1990-92		University of Arizona, Tucson AZ Classes in pursuit of Ph.D. in Hydrology.
1988-90	M.S. Hydrology/Hydrogeology	University of Nevada, Reno Thesis: Stream Morphology, Stability and Habitat in Northern Nevada
1981-83		University of Colorado, Denver, CO Graduate level water resources engineering classes.
1977-81	B.S., Civil Engineering	University of Colorado, Boulder, CO

Professional Experience

Years	Position	Duties
1993-Pr.	Hydrologic Consultant	Completion of hydrogeology studies and testimony focusing on mine dewatering, groundwater modeling, natural gas development, contaminant transport, NEPA review, and water rights for nonprofit groups and government agencies.
1999-2004	Great Basin Mine Watch, Exec Director	Responsible for reviewing and commenting on mining projects with a focus on groundwater and surface water resources, preparing appeals and litigation, organizational development and personnel management.
1992-1997	Univ of NV, Reno, Res. Assoc.	Research on riparian area and watershed management including stream morphology, aquatic habitat, cattle grazing and low-flow and flood hydrology.
1990-1992	U of AZ, Res. and Teach. Assistant	Research on rainfall/runoff processes and climate models. Taught lab sections for sophomore level "Principles of Hydrology". Received 1992 Outstanding Graduate Teaching Assistant Award in the College of Engineering
1988-1990	U of NV, Reno Res. Asst	Research on aquatic habitat, stream morphology and livestock management.
1983-1988	US Bureau of Reclamation Hydraulic Eng.	Performed hydrology planning studies on topics including floodplains, water supply, flood control, salt balance, irrigation efficiencies, sediment transport, rainfall-runoff modeling and groundwater balances.

Peer-Reviewed Publications

Myers, T., 2016. A modeling approach to siting mine facilities in northern Minnesota USA. *J Hydrology* 533: 277-290. Doi: 10.1016/j.jhydrol.2015.12.020

Myers, T., 2013. Remediation scenarios for selenium contamination, Blackfoot Watershed, southeast Idaho, USA. *Hydrogeology J.* DOI 10.1007/s10040-013-0953-8

Myers, T., 2013. Reservoir loss rates from Lake Powell and their impact on management of the Colorado River. *Journal of the American Water Resources Association*. DOI: 10.1111/jawr.12081.

Myers, T., 2012. Potential contaminant pathways from hydraulically fractured shale to aquifers. *Ground Water* 50(6): 872-882. doi: 10.1111/j.1745-6584.2012.00933.x

Myers, T., 2009. Groundwater management and coal-bed methane development in the Powder River Basin of Montana. *J Hydrology* 368:178-193.

Myers, T.J. and S. Swanson, 1997. Variation of pool properties with stream type and ungulate damage in central Nevada, USA. *Journal of Hydrology* 201-62-81

Myers, T.J. and S. Swanson, 1997. Precision of channel width and pool area measurements. *Journal of the American Water Resources Association* 33:647-659.

Myers, T.J. and S. Swanson, 1997. Stochastic modeling of pool-to-pool structure in small Nevada rangeland streams. *Water Resources Research* 33(4):877-889.

Myers, T.J. and S. Swanson, 1997. Stochastic modeling of transect-to-transect properties of Great Basin rangeland streams. *Water Resources Research* 33(4):853-864.

Myers, T.J. and S. Swanson, 1996. Long-term aquatic habitat restoration: Mahogany Creek, NV as a case study. *Water Resources Bulletin* 32:241-252

Myers, T.J. and S. Swanson, 1996. Temporal and geomorphic variations of stream stability and morphology: Mahogany Creek, NV. *Water Resources Bulletin* 32:253-265.

Myers, T.J. and S. Swanson, 1996. Stream morphologic impact of and recovery from major flooding in north-central Nevada. *Physical Geography* 17:431-445.

Myers, T.J. and S. Swanson, 1995. Impact of deferred rotation grazing on stream characteristics in Central Nevada: A case study. *North American Journal of Fisheries Management* 15:428-439.

Myers, T.J. and S. Swanson, 1992. Variation of stream stability with stream type and livestock bank damage in northern Nevada. *Water Resources Bulletin* 28:743-754.

Myers, T.J. and S. Swanson, 1992. Aquatic habitat condition index, stream type, and livestock bank damage in northern Nevada. *Water Resources Bulletin* 27:667-677.

Zonge, K.L., S. Swanson, and T. Myers, 1996. Drought year changes in streambank profiles on incised streams in the Sierra Nevada Mountains. *Geomorphology* 15:47-56.

Representative Projects

Expert Witnessing

Myers, T., 2017. Expert Report/Testimony. In the Matter of Applications 53987 through 53992, inclusive, and 54003 through 54021, inclusive, filed to appropriate the underground waters of Spring Valley, Cave Valley, Dry Lake Valley, and Delamar Valley (Hydrographic Basins 184, 180, 181, and 182), Lincoln County and White Pine County, Nevada. Nevada Division of Water Resources. Hearing September 25-October 6, 2017.

Myers, T., 2017. Expert Testimony. In the Matter of Application for Beneficial Water Use Permit No 76LJ-30102978 by Montana Artesian Water Company. Montana Department of Natural Resources. Hearing in Kalispell MT, Sept 19 -22, 2017

Myers, T., 2016. Expert Report/Testimony: In Re State Land Office Agriculture Lease No. GT-0447, Brininstool XL Ranch, LLC v. Devon Energy Production Company, Contest No. 15-006. Santa Fe, NM

Myers, T., 2014. Expert Report/Deposition: In the Matter of California Department of Parks and Recreation v. Newmont Mining Corporation, et al. Prepared for the California Department of Justice, February 2014

Myers, T., 2012. Expert Report/ Testimony at Aquifer Protection Permit Appeal Hearing, Rosemont Mine. Phoenix AZ, August and September, 2012.

Myers, T., 2011. Deposition: Northeast Natural Energy, LLC and Enroute Properties, LLC v. The City of Morgantown, WV, Civil Action No. 11-C-411, Circuit Couty of Monongalia County, WV.

Myers, T., 2011 and earlier. Expert Reports (some listed below) and Testimony. Water Rights Protest Hearings before the Nevada State Engineer, Southern Nevada Water Authority Applications for (1) Spring Valley, (2) Cave, Dry Lake, Delamar Valley, (3) Three Lakes/Tikapoo Valley.

Myers, T. 2006. Affidavit. Diamond Cross Properties, LLC, Northern Plains Resource Council, Tounge River Water Users Assoc v. State of Montana, Dept of Env Quality, Board of Oil and Gas Conservation, Dept of Natural Resources and Conservation, and Pinnacle Gas Resources, Inc, and Fidelity Exploration and Production Co., MT 22nd Judicial District Court Big Horn County, Civil Cause No. DV 05-70.

Myers, T. 2006. Expert Report/Deposition. Cole et al. v J.M. Huber Corp, and William DeLapp. U.S. Federal District Court Case No. 06-CV-0142J.

Myers, T., 2005. Nevada State Environmental Commission Appeal Hearing, Water Pollution Control Permit Renewal NEV0087001, Big Springs Mine. Prepared for Great Basin Mine Watch, Reno NV.

Myers, T. 2004. Nevada State Environmental Commission Appeal Hearing, Water Pollution Control Permit, Lone Tree Mine, Gold Quarry Mine. Prepared for Great Basin Mine Watch, Reno NV.

Reports, Reviews and Activities

Myers, T. 2017. Technical Memorandum: Impact of Developing Dixie Meadows Geothermal Utilization Project on Springs and Surface Water. Prepared for Center for Biological Diversity. July 24, 2017.

Myers, T. 2017. Technical Memorandum: Review of Bishop Tube Superfund Site and an Assessment of the Site's Proposed Residential Development. Prepared for Delaware Riverkeeper Network. March 20, 2017.

Myers, T. 2017. Technical Memorandum: Review of Dinwoody Enhanced and Production Covers. Prepared for EarthWorks and Crow Creek Conservation Alliance. Decmeber 5, 2017.

Myers, T. 2017. Technical Memorandum: Review of Final Responsiveness Summary for Aquifer Project Permit Application, Gunnison Copper Project. Prepared for Amerind Foundation, Dragoon, AZ

Myers, T. 2016. Effect of Open-Pit Mine Dewatering and Cessation on Semi-Arid River Flows. Prepared for the Progressive Leadership Alliance of Nevada.

Myers, T. 2016. International Technology Exchange, Mongolia. Working with Mongolian and Russian NGOs regarding Mining and Energy Development.

Myers, T. 2016. Technical Memorandum: Completeness Review of the Mine Operating Permit Application, Black Butte Copper Project, Meagher County MT. Prepared for Montana Chapter, Trout Unlimited.

Myers, T. 2016. Technical Memorandum. Response to the US Fish and Wildlife Service Hydrologic Reasoning in its Response to the Center for Biological Diversity's Notice of Intent to Sue to Reopen Consultation on Various Memorandums of Agreement Regarding the Muddy River Springs. Prepared for the Center for Biological Diversity, September 10, 2016.

Myers, T., 2016. Technical Memorandum, Review of the Draft Environmental Impact Statement, Copper Flat, Sierra County, NM. Prepared for Ladder Ranch, Inc. and New Mexico Environmental Law Center

Myers, T., 2016. Technical Memorandum, Review of the Draft Supplemental Environmental Impact Statement for the Donlin Gold Project. Prepared for the Northern Alaska Environmental Center.

Myers, T., 2016. Technical Memorandum, Review of the Draft Supplemental Environmental Impact Statement for the Rock Creek Project, Sanders County, MT. Prepared for the Rock Creek Alliance.

Myers, T. 2016. Technical Memorandum, Twin Metals Mine and the Peter Mitchell Pit, Simulation of the Development of the Peter Mitchell Pit and Its Effects on the Proposed Twin Metals Tailings Impoundment. Prepared for Northeastern Minnesotans for Wilderness.

Myers, T., 2015. Conceptual Flow and Transport Model, Uranium Plume near the Homestake Millsite, Milan, NM. Prepared for Bluewater Valley Downstream Alliance. Marcy 16, 2015.

Myers, T., 2015. Hydrogeology of the Humboldt River Basin, Impacts of Open-pit Mine Dewatering and Pit Lake Formation. Prepared for the Progressive Leadership Alliance of Nevada and Great Basin Resource Watch, Revised June 2015.

Myers, T., 2015. Letter Report: Comments on the Draft Supplemental Environmental Impact Review for the Panoche Valley Solar Project. Prepared for Adams Broadwell Joseph and Cardozo, San Francisco CA

Myers, T., 2015. Technical Memorandum: Review of the Final Environmental Impact Statement, NorthMet Mining Project and Land Exchange. Prepared for Minnesota Center for Environmental Advocacy.

Myers, T., 2015. Technical Memorandum – Review of Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. Prepared for Delaware Riverkeeper Network. August 24, 2015.

Myers, T., 2015. Technical Memorandum – Review of Finger Lakes LPG Storage, LLC, Proposed LPG Storage Facility. Prepared for Earthjustice, New York. January 13, 2015

Myers, T., 2015. Technical Memorandum – Review of Pennsylvania Governor's Executive Order Concerning Hydraulic Fracturing in Pennsylvania State Parks and Forest. Prepared for Delaware River Keeper, January 9, 2015.

Myers, T., 2015. Technical Memorandum – Review of Water Supply Assessment, Village at Squaw Valley. Prepared for Sierra Watch, July 13, 2015.

Myers, T., 2014. Groundwater Flow and Transport Modeling, NorthMet Mine and Plant Site. Prepared for the Minnesota Center for Environmental Advocacy.

Myers, T., 2014. Letter Report: Comments on the Environmental Assessment for the Proposed Photovoltaic Array Proposed for Ft Irwin CA. Prepared for Adams Broadwell Joseph and Cardozo, San Francisco CA, October 13, 2014

Myers, T., 2014. Review of the Water Quality Modeling, NorthMet Mine and Plant Site, Minnesota. Prepared for Minnesota Center for Environmental Advocacy.

Myers, T. 2014. Technical Memorandum: Review of Performance Standards, Center for Sustainable Shale Development. Prepared for Delaware River Keeper. May 8, 2014.

Myers, T. 2014. Technical Memorandum: Review of the Hydrogeologic Aspects of the Draft Environmental Impact Statement, Haile Gold Mine, Lancaster County, South Carolina. Prepared for Southern Environmental Law Center, May 8 2014.

Myers, T., 2014. Technical Memorandum: Review of the Supplemental Draft Environmental Impact Statement, NorthMet Mining Project and Land Exchange. Prepared for Minnesota Center for Environmental Advocacy. March 10, 2014

Myers, T. 2014. Technical Memorandum: Twin Metals and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining. Prepared for Northeastern Minnesotans for Wilderness. August 8 2014

Myers, T. 2012-3. Participation in EPA Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Study. US Environmental Protection Agency, Washington DC.

Myers, T., 2013. DRAFT: Chapter 5.1: Water Quality. Initiative for Responsible Mining.

Myers, T., 2013. DRAFT: Chapter 5.2: Water Quantity. Initiative for Responsible Mining.

Myers, T., 2013. Technical Memorandum: Comments on Encana Oil and Gas Inc.'s Application for the Madison Aquifer to be Exempt Wyoming Oil and Gas Conservation Commission Docket No. 3-2013. Prepared for Natural Resources Defense Council, Powder River Basin Council. June 12, 2013.

Myers, T. 2013. Technical Memorandum: Impact Analysis: Wishbone Hill Water Right Application. Prepared for Trustees for Alaska

Myers, T, 2013. Technical Memorandum: Review of Montanore Mine Dewatering Instream Flow Methodology. Prepared for Save our Cabinets, Earthworks. March 26, 2013

Myers, T. 2012. Technical Memorandum: Chuitna Coal Mine Project, Review of Arcadis DRAFT Hydrogeologic Conceptual Site Model Update and Associated Documents. Prepared for Cook Inletkeeper. May 11, 2012.

Myers, T., 2012. Technical Memorandum, Review of DRAFT: Investigation of Ground Water Contamination near Pavillion Wyoming Prepared by the Environmental Protection Agency, Ada OK. April 19, 2012.

Myers, T., 2012. Participation in: Keystone Center Independent Science Panel, Pebble Mine. Anchorage AK, October 1-5, 2012.

Myers, T., 2012. Technical Memorandum, Review and Analysis, Revised Draft, Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs. Prepared for Natural Resources Defense Council.

Myers, T., 2012. Technical Memorandum, Review of the Special Use Permit PP2011-035-Camilletti 21-10, Groundwater Monitoring Requirements. Prepared for Routt County Board of Commissioners and the Routt County Planning Department. June 19, 2012.

Myers, T., 2012. Drawdown at U.S. Forest Service Selected Monitoring Points, Myers Rosemont Groundwater Model Report. Prepared for Pima County, AZ. March 22, 2012.

Myers, T. 2011. Baseflow Conditions in the Chuitna River and Watersheds 2002, 2003, and 2004 and the Suitability of the Area for Surface Coal Mining. January 14, 2011.

Myers, T., 2011. Hydrogeology of Cave, Dry Lake and Delamar Valleys, Impacts of pumping underground water right applications #53987 through 53092. Presented to the Office of the Nevada State Engineer On behalf of Great Basin Water Network.

Myers, T., 2011. Hydrogeology of Spring Valley and Surrounding Areas, Part A: Conceptual Flow Model. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation.

Myers, T., 2011. Hydrogeology of Spring Valley and Surrounding Areas, Part B: Groundwater Model of Snake Valley and Surrounding Area. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation.

Myers, T., 2011. Hydrogeology of Spring Valley and Surrounding Areas, PART C: IMPACTS OF PUMPING UNDERGROUND WATER RIGHT APPLICATIONS #54003 THROUGH 54021.

Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation.

Myers, T., 2011. Rebuttal Report: Part 2, Review of Groundwater Model Submitted by Southern Nevada Authority and Comparison with the Myers Model. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation.

Myers, T. 2011. Rebuttal Report: Part 3, Prediction of Impacts Caused by Southern Nevada Water Authority Pumping Groundwater From Distributed Pumping Options for Spring Valley, Cave Valley, Dry Lake Valley, and Delamar Valley. Presented to the Nevada State Engineer on behalf of Great Basin Water Network and the Confederated Tribes of the Goshute Reservation.

Myers, T., 2011. Baseflow Selenium Transport from Phosphate Mines in the Blackfoot River Watershed Through the Wells Formation to the Blackfoot River, Prepared for the Greater Yellowstone Coalition.

Myers, T., 2011. Blackfoot River Watershed, Groundwater Selenium Loading and Remediation. Prepared for the Greater Yellowstone Coalition.

Myers, T., 2011. Technical Memorandum Review of the Proposed Montanore Mine Supplemental Draft Environmental Impact Statement and Supporting Groundwater Models

Myers, T., 2010. Planning the Colorado River in a Changing Climate, Colorado River Simulation System (CRSS) Reservoir Loss Rates in Lakes Powell and Mead and their Use in CRSS. Prepared for Glen Canyon Institute.

Myers, T., 2010. Technical Memorandum, Updated Groundwater Modeling Report, Proposed Rosemont Open Pit Mining Project. Prepared for Pima County and Pima County Regional Flood Control District

Myers, T., 2009. Monitoring Groundwater Quality Near Unconventional Methane Gas Development Projects, A Primer for Residents Concerned about Their Water. Prepared for Natural Resources Defense Council. New York, New York.

Myers, T., 2009. Technical Memorandum, Review and Analysis of the Hydrology and Groundwater and Contaminant Transport Modeling of the Draft Environmental Impact Statement Blackfoot Bridge Mine, July 2009. Prepared for Greater Yellowstone Coalition, Idaho Falls, Idaho.

Myers, T., 2008. Hydrogeology of the Carbonate Aquifer System, Nevada and Utah With Emphasize on Regional Springs and Impacts of Water Rights Development. Prepared for: Defenders of Wildlife, Washington, D.C. June 1, 2008.

Myers, T., 2008. Hydrogeology of the Muddy River Springs Area, Impacts of Water Rights Development. Prepared for: Defenders of Wildlife, Washington, D.C. May 1, 2008

Myers, T., 2008. Hydrogeology of the Santa Rita Rosemont Project Site, Numerical Groundwater Modeling of the Conceptual Flow Model and Effects of the Construction of the Proposed Open Pit, April 2008. Prepared for: Pima County Regional Flood Control District, Tucson AZ.

Myers, T., 2008. Technical Memorandum, Review, Record of Decision, Environmental Impact Statement Smoky Canyon Mine, Panels F&G, U.S. Department of the Interior, Bureau of Land Management.

Prepared for Natural Resources Defense Council, San Francisco, CA and Greater Yellowstone Coalition, Idaho Falls, ID. Reno NV.

Myers, T., 2007. Groundwater Flow and Contaminant Transport at the Smoky Canyon Mine, Proposed Panels F and G. Prepared for Natural Resources Defense Council, San Francisco, CA and Greater Yellowstone Coalition, Idaho Falls, ID. Reno NV. December 11, 2007.

Myers, T., 2007. Hydrogeology, Groundwater Flow and Contaminant Transport at the Smoky Canyon Mine, Documentation of a Groundwater Flow and Contaminant Transport Model. Prepared for Natural Resources Defense Council, San Francisco, CA and Greater Yellowstone Coalition, Idaho Falls, ID. Reno NV, December 7, 2007.

Myers, T., 2007. Review of Hydrogeology and Water Resources for the Final Environmental Impact Statement, Smoky Canyon Mine, Panels F and G and Supporting Documents. Prepared for Natural Resources Defense Council, San Francisco, CA and Greater Yellowstone Coalition, Idaho Falls, ID. Reno, NV. December 12, 2007.

Myers, T., 2007. Hydrogeology of the Powder River Basin of Southeast Montana Development of a Three-Dimensional Groundwater Flow Model. Prepared for Northern Plains Resource Council. February 12 2007.

Myers, T., 2007. Hydrogeology of the Santa Rita Rosemont Project Site, Conceptual Flow Model and Water Balance, Prepared for: Pima County Flood Control District, Tucson AZ

Myers, T., 2006. Review of Mine Dewatering on the Carlin Trend, Predictions and Reality. Prepared for Great Basin Mine Watch, Reno, NV

Myers, T., 2006. Hydrogeology of Spring Valley and Effects of Groundwater Development Proposed by the Southern Nevada Water Authority, White Pine and Lincoln County, Nevada. Prepared for Western Environmental Law Center for Water Rights Protest Hearing.

Myers, T., 2006. Potential Effects of Coal Bed Methane Development on Water Levels, Wells and Springs of the Pinnacle Gas Resource, Dietz Project In the Powder River Basin of Southeast Montana. Affidavit prepared for Northern Plains Resource Council, April 4 2006.

Myers, T., 2006. Review of Hydrogeology and Water Resources for the Draft Environmental Impact Statement, Smoky Canyon Mine, Panels F and G, Technical Report 2006-01-Smoky Canyon. Prepared for Natural Resources Defense Council.

Myers, T., 2006. Review of Nestle Waters North America Inc. Water Bottling Project Draft Environmental Impact Report / Environmental Assessment. Prepared for McCloud Watershed Council, McCloud CA.

Myers, T., 2005. Hydrology Report Regarding Potential Effects of Southern Nevada Water Authority's Proposed Change in the Point of Diversion of Water Rights from Tikapoo Valley South and Three Lakes Valley North to Three Lakes Valley South. Prepared for Western Environmental Law Center for Water Rights Protest Hearing

Myers, T., 2005. Review of Draft Supplemental Environmental Impact Statement, Ruby Hill Mine Expansion: East Archimedes Project NV063-EIS04-34, Technical Report 2005-05-GBMW. Prepared for Great Basin Mine Watch.

Myers, T., 2005. Hydrogeology of the Powder River Basin of Southeast Montana, Development of a Three-Dimensional Groundwater Flow Model. Prepared for Northern Plains Resource Council, Billings, MT in support of pending litigation.

Myers, T., 2005. Potential Effects of Coal Bed Methane Development on Water Levels, Wells and Springs In the Powder River Basin of Southeast Montana. Prepared for Northern Plains Resource Council, Billings, MT.

Myers, T., 2004. An Assessment of Contaminant Transport, Sunset Hills Subdivision and the Anaconda Yerington Copper Mine, Technical Report 2004-01-GBMW. Prepared for Great Basin Mine Watch.

Myers, T., 2004. Technical Memorandum: Pipeline Infiltration Project Groundwater Contamination. Prepared for Great Basin Mine Watch.

Myers, T., 2004. Technical Report Seepage From Waste Rock Dump to Surface Water The Jerritt Canyon Mine, Technical Report 2004-03-GBMW. Prepared for Great Basin Mine Watch.

Myers, T., 2001. An Assessment of Diversions and Water Rights: Smith and Mason Valleys, NV. Prepared for the Bureau of Land Management, Carson City, NV.

Myers, T., 2001. Hydrogeology of the Basin Fill Aquifer in Mason Valley, Nevada: Effects of Water Rights Transfers. Prepared for the Bureau of Land Management, Carson City, NV.

Myers, T., 2001. Hydrology and Water Balance, Smith Valley, NV: Impacts of Water Rights Transfers. Prepared for the Bureau of Land Management, Carson City, NV

Myers, T., 2000. Alternative Modeling of the Gold Quarry Mine, Documentation of the Model, Comparison of Mitigation Scenarios, and Analysis of Assumptions. Prepared for Great Basin Mine Watch. Center for Science in Public Participation, Bozeman MT.

Myers, T., 2000. Environmental and Economic Impacts of Mining in Eureka County. Prepared for the Dept. Of Applied Statistics and Economics, University of Nevada, Reno.

Myers, T., 1999. Water Balance of Lake Powell, An Assessment of Groundwater Seepage and Evaporation. Prepared for the Glen Canyon Institute, Salt Lake City, UT.

Myers, T., 1998. Hydrogeology of the Humboldt River: Impacts of Open-pit Mine Dewatering and Pit Lake Formation. Prepared for Great Basin Mine Watch, Reno, NV.

Selected Abstracts, Magazine and Proceedings Articles

Myers, T., 2014. Reservoir Loss Rates, Lakes Mead and Powell and Fill Mead First. INVITED PRESENTATION at 2014 Future of the Colorado Plateau Forum – Drought and the Colorado

River. http://musnaz.org/educational-programs/public-programs/future-of-the-colorado-plateau-forums/

Myers, T., 2013. Three-dimensional Groundwater and Contaminant Flow around Marcellus Gas Development. INVITED PRESENTATION at 2013 Associated Engineering Geologists Conference, Seattle WA.

Myers, T., 2012. Mine Dewatering: Humboldt River Update. INVITED PRESENTATION at 2012 Nevada Water Resources Association Annual Conference.

Myers, T., 2012. Reservoir loss rates from Lake Powell, and long-term management of the Colorado River system. 2012 Nevada Water Resources Association Annual Conference

Myers, T., 2011. Reservoir loss rates from Lake Powell, and long-term management of the Colorado River system. 2011 Fall Conference, American Geophysical Union.

Myers, T., 2006. Modeling Coal Bed Methane Well Pumpage with a MODFLOW DRAIN Boundary. In MODFLOW and More 2006 Managing Ground Water Systems, Proceedings. International Groundwater Modeling Center, Golden CO. May 21-24, 2006.

Myers, T., 2006. Proceed Carefully: Much Remains Unknown, *Southwest Hydrology 5(3)*, May/June 2006, pages 14-16.

Myers, T., 2004. Monitoring Well Screening and the Determination of Groundwater Degradation, Annual Meeting of the Nevada Water Resources Association, Mesquite, NV. February 27-28, 2004.

Myers, T., 2001. Impacts of the conceptual model of mine dewatering pumpage on predicted fluxes and drawdown. In MODFLOW 2001 and Other Modeling Odysseys, Proceedings, Volume 1. September 11-14, 2001. International Ground Water Modeling Center, Golden, Colorado.

Myers, T., 1997. Groundwater management implications of open-pit mine dewatering in northern Nevada. In Kendall, D.R. (ed.), Conjunctive Use of Water Resources: Aquifer Storage and Recovery. AWRA Symposium, Long Beach California. October 19-23, 1997

Myers, T., 1997. Groundwater management implications of open-pit mine dewatering in northern Nevada. In Life in a Closed Basin, Nevada Water Resources Association, October 8-10, 1997, Elko, NV.

Myers, T., 1997. Uncertainties in the hydrologic modeling of pit lake refill. American Chemical Society Annual Meeting, Las Vegas, NV, Sept. 8-12, 1997.

Myers, T., 1997. Use of groundwater modeling and geographic information systems in water marketing. In Warwick, J.J. (ed.), Water Resources Education, Training, and Practice: Opportunities for the Next Century. AWRA Symposium, Keystone, Colo. June 29-July 3, 1997.

Myers, T., 1995. Decreased surface water flows due to alluvial pumping in the Walker River valley. Annual Meeting of the Nevada Water Resources Association, Reno, NV, March 14-15, 1995.

Special Coursework

Years	Course	Sponsor

2011	Hydraulic Fracturing of the Marcellus Shale	National Groundwater Association
2008	Fractured Rock Analysis	MidWest Geoscience
2005	Groundwater Sampling Field Course	Nielson Environmental Field School
2004	Environmental Forensics	National Groundwater Association
2004 and -5	Groundwater and Environmental Law	National Groundwater Association

Glenn Miller, Ph.D.

Professor, University of Nevada
Department of Natural Resources and Environmental Science
University of Nevada/Mail Stop 199
1664 North Virginia Street
Reno, Nevada 89557
Office: (775) 784-4108
Email: gcmiller@unr.edu

Glenn C. Miller is a Professor of Natural Resources and Environmental Science at the University of Nevada, Reno. He has a B.S. in Chemistry from the University of California, Santa Barbara and a Ph.D. in Agricultural and Environmental Chemistry (1977) from the University of California at Davis. Following graduate studies, he spent a year of postdoctoral study at the EPA's Environmental Research Laboratory in Athens, Georgia. He has been on the UNR faculty since 1978 and was Director of the Graduate Program in Environmental Sciences and Health from 1996-2006 and Director of the Center for Environmental Sciences and Engineering from 1999-2003.

EDUCATION

B.S. 1972, University of California, Santa Barbara
Ph.D. 1977, University of California, Davis

REPRESENTATIVE PUBLICATIONS

Journals

Neupane, B., Shintani, D., Coronella, C., Lin, H., Miller, G. C. 2016, Grindelia squarrosa: A Potential Arid Lands Biofuel Plant., *Journal of Sustainable Chemistry and Engineering, 5(1), 995–1001*

Woodrow, J., Lepage, J., Miller, G. C., Hebert, V. 2014, Determination of Methyl Isocyanate in Outdoor Residential Air Near Metam-sodium Soil Fumigations., Journal of Agricultural and Food Chemistry, 62, 8921-8927.

Suzuki N, Miller G, Sejima H, Harper J, Mittler R. 2013, Enhanced seed production under prolonged heat stress conditions in Arabidopsis thaliana plants deficient in cytosolic ascorbate peroxidase 2., Journal of Experimental Botany 64: 253-63

Lin, H., Strull, J., Liu, Y., Karmiol, Z., Plank, K., Miller, G. C., Guo, Z. 2012, High yield production of levulinic acid by catalytic partial oxidation of cellulose in aqueous media., Energy and Environmental Science, 5, 9773-9777.

Woodrow, J., Seiber, J., Miller, G. C. 2010, Correlation to Estimate Emission Rates for Soil-Applied Fumigants., J. Agricultural and Food Chemistry

Woodrow, J. E., Seiber, J. N., Miller, G. C. 2008, Acrylamide release resulting from sunlight irradiation of aqueous polyacrylamide/iron mixtures., Journal of Agriculture and Food Chemistry, 56(8), 2773-2779.

Luo, Q., Tsukamoto, T., Zamzow, K., Miller, G. C. 2008, Arsenic, Selenium, and Sulfate Removal using an Ethanol-enhanced Sulfate-Reducing Bioreactor., International Mine Water Association, 26(2), 1-12.

Hebert, V.R, C. Hoonhout and G.C. Miller 2000, Reactivity of Certain Organophosphorus Insecticides Toward Hydroxyl Radicals at Elevated Air Temperatures, Journal of Agricultural and Food Chemistry 48:1922-1928

Tsukamoto, T.K., and G.C. Miller 1999, Methanol as a Carbon Source for Bioremediation of Acid Mine Drainage, Water Research, 33:1365-1370

V. R. Hebert and G.C. Miller 1998, Gas Phase Photolysis of Phorate, Chemosphere 36:2057-2066

Book or Chapter(s) in Books

Masaitis, A., Miller, G. C. 2015, Development of the stakeholders' engagement plan as a mining social responsibility practice., Conflict Resolution in the Mining Industry (pp. 14). American Chemical Society: American Geophysical Union.

Masaitis, A., Miller, G. C. 2013, Reduction of Conflicts in Mining Development Using "Good Neighbor Agreements., In J.L. Drake, Y.Y Kontar and G.S. Rife (Ed.), New Trends in Earth-Science Outreach and Engagement: The Nature of Communication (vol. 38, pp. 73-81). New York: Springer.

Miller, G.C., C. Hoonhout, W.W. Miller, M.M. Miller 1999, Geochemistry of Closed Heaps: A Rationale for Drainage Water Quality, D. Kosich and G.C. Miller, eds, "Closure, Remediation and Management of Precious Metals Heap Leach Facilities", University of Nevada, (1999)

J. Geddes and G. C. Miller 1998, Photolysis of Organics in the Environment, D.L Macalady, ed. -Perspectives in Environmental Chemistry, Oxford University Press (1998) p 195-209.

J. Geddes and G. C. Miller 1998, Photolysis of Organics in the Environment, D.L Macalady, ed. -Perspectives in Environmental Chemistry, Oxford University Press (1998) p 195-209.

Presentations

Miller, G. C. 2011, A Grand Challenge: sustainable Natural Resources Development on a Small Planet, Non-Academic, Long Term Management Challenges at Hard Rock Mining Sites, National Academy of Science

Bulletin/Reports

Lu, Z., Miller, G. C., Hebert, V. 2017, Laboratory Measured Emission Losses of Methyl Isothiocyanate at Paciic Northwest Soil Surface Fumigation Temperatures., Bulletin of Environmental Contamination and Toxicology, 5.