Catskill Mountainkeeper

Please find attached cover letter containing comments from Kathleen Nolan, MD, MSL, Senior Research Director for Catskill Mountainkeeper, along with referenced attachment "HydroQuestBrineSpreadingReportwithAddendas-20180329.pdf).

We appreciate the opportunity to submit these comments.

Sincerely,
/Kathleen Nolan, MD, MSL/

March 30, 2018

Commissioners
Delaware River Basin Commission
PO Box 7360
West Trenton NJ 08628-9522

Re: Proposed Special Regulations Part 440 and related documents

Dear Commissioners:

Please accept these comments on behalf of Catskill Mountainkeeper regarding the Delaware River Basin Commission's "Proposed Special Regulations Part 440 – Hydraulic Fracturing in Shale and Other Formations," also announced as "Proposed Amendments to the Administrative Manual and Special Regulations Regarding Hydraulic Fracturing Activities; [and] Additional Clarifying Amendments; 18 CFR Parts 401 and 440."

Catskill Mountainkeeper is a registered 501(c)(3) non-profit organization that advocates for the Catskills region. CMK works with and represents a network of concerned citizens in areas within and surrounding the Delaware River Basin. Through the DRBC's online portal for submission of comments on the proposed regulations, Catskill Mountainkeeper has submitted 2,182 comments collected on behalf of these citizens. We offer here additional comments on specific aspects of the proposed regulations, focused primarily on the hazards of introducing fracking wastes, as well as wastes from conventional oil and gas wells, into the waters of the Basin, including drinking supply waters.

Catskill Mountainkeeper acknowledges and deeply respects the foundational obligations of the Delaware River Basin Commission: to protect water quality in the Delaware River Basin and thereby protect human health and wellbeing. We therefore applaud the careful attention to water quality threats from hydraulic fracturing (fracking) evidenced in the proposed amendments to existing DRBC regulations. We thoroughly endorse the Commission's decision to ban hydraulic fracturing in the Basin, as incompatible with the Commission's mission, due to numerous, irremediable, potential mechanisms for water contamination, including but not limited to well bore casing failure, cement bond failure, casing and pipeline corrosion, spills (during drilling, storage, and transportation), intentional and unintentional releases, pressure bulb events, and seepage over time. These mechanisms lead to widely known and, in 2018, very well documented adverse impacts on water quality,[1] which the proposed amendments reference and address in the

[1] 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. (accessed online 3/30/2018 at http://concernedhealthny.org/compendium): see Water contamination, pp. 48ff.

proposed ban on fracking. Research reports also increasingly document the related adverse impacts on ecological systems and human health that follow from contamination of water, air, and soils near fracking activities and fracking infrastructure, such as compressor stations, pipelines, pigging stations, and natural gas-fired power plants.[2]

In addition, we urge the Commission to take note of the uncontrolled character of fracking's underground explosions and resulting induced seismicity, that is, earthquakes caused by both fracking itself and by underground injection of wastewater. The primary action of fracking, that is, setting off high-pressure explosions underground and injecting slippery fluids, is described by engineers working for the oil and gas industry – and by text in the proposed amendments – as taking place in shale formations that are "separated from potential freshwater aquifers by thousands of feet of sandstones and shales of moderate to low permeability."[3] However, precise seismologic recordings at the most carefully studied fracking wells in the world, in Greene County, Pennsylvania, contradict such assertions by recording multiple, long induced fractures that extend above the hypothesized "frac barrier."[4] Research conducted earlier this year in New York on hydrocarbon and brine migration[5] confirms earlier modeling studies[6] that faulting creates pathways for migration from deep shale layers to shallower aquifers. Not surprisingly, fracking activity itself can cause earthquakes, as has been seen across the United States and in Canada, and as close to the Delaware River Basin as Lawrence County, Pennsylvania.[7]

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[2] Ibid.: see Public health effects, measured directly, pp. 114ff.

[3] Delaware River Basin Commission. 18 CFR Parts 401 and 440: Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities; Additional Clarifying Amendments

[4] Hammack, R., Harbert, W., Sharma, S., Stewart, B. W., Capo, R. C., Wall, A. J., . . . Veloski, G. (2014). An evaluation of fracture growth and gas/fluid migration as horizontal Marcellus Shale gas wells are hydraulically fractured in Greene County, Pennsylvania. *NETL-TRS-3-2014: EPAct Technical Report Series. US Dept of Energy, National Energy Technology Laboratory*: Pittsburgh PA. Retrieved from http://www.netl.doe.gov/File%20Library/Research/onsite%20research/publications/NETL-TRS-3-2014_Greene-County-Site_20140915_1_1.pdf

[5] Kreuzer, RL et al. (2018). Structural and Hydrogeological Controls on Hydrocarbon and Brine Migration into Drinking Water Aquifers in Southern New York. Groundwater. 56. 10.1111/gwat.12638.

[6] Myers, T. (2012). Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers. Groundwater, 50: 872-882. doi:10.1111/j.1745-6584.2012.00933.x (accessed online 3/30/2018 at https://www.scribd.com/document/244283158/Wiley-Contaminant-pathways-fr-hydraulically-fract-shale-1-pdf)

[7] In Pennsylvania, the Department of Environment Protection (DEP) announced early in 2017 that a series of small earthquakes in Lawrence County had been induced by fracturing of wells in the Utica Shale (http://powersource.post-gazette.com/powersource/policy-powersource/2017/02/16/DEP-Pennsylvania-Lawrence-County-earthquakes-appear-linked-to-fracking-Hilcorp-Energy/stories/201702160176). DEP officials held a webinar to discuss the situation and formulate "procedures to reduce seismic risk going forward," but no formal report or regulatory changes have yet been made public (http://www.ahs.dep.pa.gov/NewsRoomPublic/articleviewer.aspx?id=21145&typeid=1).

The deliberations of the Commissioners and the draft regulations should reflect these facts. Moreover, since injecting fracking waste underground poses more risk than fracking in terms of generating earthquakes and carries greater risk of contamination of water with a wider variety of toxic compounds, the proposed amendments should directly address induced seismicity and explicitly ban any underground injection of fracking wastewater in the Delaware River Basin.

Non-gaseous oil and gas waste products fall roughly into two categories: liquid waste and solid waste (we will not address gaseous wastes, which include methane, radon, and volatile aromatic compounds but do not generally pose a direct threat to water quality). Both liquid and solid forms of fracking waste, as well as waste from conventional oil and gas development, can contain toxic chemicals, hydrocarbons, brines, heavy metals, and radioactive contaminants. The toxic chemicals originate primarily in the "fracking fluid" injected underground to fracture and keep open natural gas bearing shale deposits, while the hydrocarbons, brines, heavy metals, and radioactive contaminates originate from targeted deep shale layers, or in the case of conventional wells, from sandstone layers. In simple terms, the fracking fluids dissolve the heavy metals and radioactive elements, mobilizing them and potentially contaminating any waste that emerges from the well, whether liquid, solid, or semi-solid material. As described by the United States Environmental Protection Agency (EPA), "Radioactive wastes from oil and gas drilling take the form of produced water, drilling mud, sludge, slimes, or evaporation ponds and pits. It can also concentrate in the mineral scales that form in pipes (pipe scale), storage tanks, or other extraction equipment."[8]

The toxic nature of these waste materials has been well described, despite laws protecting the proprietary nature of the fracking fluids. Produced waters commonly exhibit highly elevated concentrations of bromide, chloride, hardness as calcium carbonate, total dissolved solids, barium, boron, calcium, iron, lithium, magnesium, manganese, potassium, sodium, and strontium. Furthermore, these fluids sometimes also include many additional chemicals including, but not limited to the following: pyridine, ethylbenzene; benzene; toluene; xylenes; 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene, arsenic; assorted phthalates; assorted metals; fluorene; phenol; 2-propanol; butyl alcohol; propylene glycol; ethanol; phenanthrene and other chemical compounds." Other drilling mud and fluid contaminants of note include aluminum, titanium, 2-butanone, and 1,2,4-trimethylbenzene.[9]

Many of these waste products should be quite familiar to us, having been identified as contaminants in soil, sediment, and water at a hazardous waste site that later came to be known as the Love Canal Superfund site in Niagara Falls, New York. The Love Canal property, having been used in the 1930s and 1940s as a landfill for the disposal of over 21,000 tons of various chemical wastes, contaminated nearby groundwater, which then rose to the surface and drained into the Niagara River, contaminating it, as well. Contaminants also migrated from the landfill to

[8] http://www.mde.maryland.gov/programs/Land/mining/marcellus/Documents/EPA_Radioactive_Wastes_from_Oil_Gas_Drilling(2012).pdf (accessed online 3/30/2018).

[9] See, for example, Hayes, 2009: Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas, accessed online 3/30/2018 at https://www.scribd.com/document/111953961/Sampling-and-Analysis-of-Water-Streams)

local sewers, which drained into nearby creeks. Eventually, approximately 950 families had to be evacuated from the area surrounding the landfill. Contamination at the site ultimately led to the passage of Federal Superfund legislation.

Radiation was not a major concern at the Love Canal Superfund site, but it is of major concern in regard to fracking waste from the Marcellus Shale. In 2014, a group of leading public health experts wrote to Governor Cuomo, urging his administration to "conduct studies and a human health risk assessment of the occurrence of radon and radium during drilling for natural gas before deciding whether to allow drilling in New York's portion of the Marcellus shale or the distribution to New Yorkers of Marcellus shale gas containing unhealthy levels of radon" and "to make public any and all data collected about the presence of these two carcinogenic elements in Marcellus shale drilling."[10]

Multiple studies have found that waste from fracking can be radioactive — and in some cases, highly radioactive. A report from the United States Geological Survey (USGS) documented that wastewater from unconventionally drilled wells in Pennsylvania and conventionally drilled wells in New York contained thousands of times more radioactivity than the federal limit for drinking water and hundreds of times more radioactivity than allowed by the Nuclear Regulatory Commission for nuclear plant discharges.[11] In 2011, the USGS reported that waste water from oil and gas wells in New York and Pennsylvania, including those in the Marcellus shale, show distinctly higher levels of radium than those reported for other formations.[12]

A study from Penn State's Department of Geosciences also found that fracking wastewater contains high levels of radium, along with the toxic heavy metal barium.[13] Horizontally drilled wells are more likely to produce high levels of radioactive waste than other types of wells, because the horizontal pipe is exposed throughout its roughly mile-long length to whatever levels of radiation are present in the deep shale layers. As summarized by the EPA, "Radionuclides in these wastes [from oil and gas drilling] are primarily radium-226, radium-228, and radon gas. The radon is released to the atmosphere, while the produced water and mud containing radium are placed in ponds or pits for evaporation, re-use, or recovery."[14] The EPA goes on to say that the people most likely to be exposed to this source of radiation are "workers at the site." That may be true, yet the EPA's guidance to workers should give us pause, especially as it applies *a fortiori* to the general public. Under a heading "What you can do to protect yourself," the EPA advises as follows: "Do not re-use or bring home discarded equipment or material such as pipes, devices, bricks, rocks, or **water**" (emphasis added); "Limit exposures and disturbance of the

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[10] http://concernedhealthny.org/wp-content/uploads/2014/05/CuomoLetter-RadiationHazards20140508.pdf (accessed online 3/30/2018)
[11] Rowan, EL et al. Radium Content of Oil- and Gas-Field Produced Waters in the Northern Appalachian Basin (USA): Summary and Discussion of Data. USGS Scientific Investigations Report 2011–5135 (accessed online 3/30/2018 at https://pubs.usgs.gov/sir/2011/5135/pdf/sir2011-5135.pdf)
[12] E.L. Rowan and T.F. Kraemer, U.S. Geological Survey, Radon-222 Content of Natural Gas Samples from Upper and Middle Devonian Sandstone and Shale Reservoirs in Pennsylvania: Preliminary Data, 2012. (Accessed online 3/30/2018 at http://pubs.usgs.gov/of/2012/1159)
[13] Haluszczak, LO, et al. Geochemical evaluation of flowback brine from Marcellus gas wells in Pennsylvania, USA. Appl.Geochem. (2012). (accessed online 3/30/2018 at http://dx.doi.org/10.1016/j.apgeochem.2012.10.002)
[14] http://www.epa.gov/radtown/drilling-waste.html (accessed online 3/30/2018)

production site and any abandoned equipment"; and "Do not handle, dispose or re-use abandoned equipment used at drilling sites."

The public is exposed to wastes from oil and gas development through several mechanisms: 1) fluids delivered to treatment plants unable to remove the contaminants; 2) waste materials inadequately contained at landfills; 3) legally authorized applications to roads and fields; 4) intentional, illegal dumping in fields and streams; 5) toxic spills during transport; 6) leaching from toxic wastes buried underground; and 7) direct contamination of drinking water sources from fracking activities. Almost all of these routes of contamination pose a threat to areas that can be far removed from the site of fracking or conventional oil and gas activities.

Given the toxic composition of fracking waste, which can include brines (with elevated levels of chloride, total dissolved solids, sodium, calcium and magnesium), unknown fracking agents, heavy metals, and radioactive materials, the regulations should, rather than invite case-by-case analysis on individual dockets (see *Sections 440.5(f)* through *(h)*), unequivocally ban the importation of fracking and other oil and gas waste into the Basin, until and unless safe mechanisms of transporting fracking waste are devised and treatment mechanisms and plants become available that provide adequate and effective removal of all regularly encountered toxins in fracking waste, prior to such waste entering the Basin. Moreover, since brines from conventional wells also present major contaminant issues, we urge the Commission to take this opportunity to ban the importation of produced waters and solid waste from both conventional and unconventional wells.

Fracking wastes are materials clearly recognizable in other circumstances as "hazardous wastes"; indeed, many of them are found on the EPA's list of "Priority Chemicals" to be eliminated from or substantially reduced through limiting production, or at a minimum, recovered or recycled. Unfortunately, under federal law, fracking wastes are not treated as hazardous wastes due to exemptions that use the power of pencil and paper – and the human imagination – to wipe out almost all legal obligation to protect the public from what would otherwise be preventable, highly toxic, and potentially lethal exposures. The DRBC should not utilize the Delaware River Basin as a means to relieve the oil and gas industry of its obligations to handle its wastes without harming the public. The DRBC's revised regulations should prohibit the transport of oil and gas waste or waste by-products into the Basin for treatment, discharge, disposal, or storage purposes; prohibit the acceptance of wastewater from oil or natural gas extraction activities at wastewater facilities and landfills in the Basin; and as far as possible under existing federal laws and regulations, treat waste as hazardous waste on the basis of its hazardous characteristics, without regard to its origin.

To provide any mechanism at this point for introducing and discharging oil and gas waste fluids, including produced water, directly into streams, estuaries, and other receiving waters in the Basin, as is proposed in the draft regulations (*Section 440.5 – Produced Water* and *DRBC Guidelines for Determining Background Concentrations in Surface Waters under Special Regulations, Part 440 – Hydraulic Fracturing in Shale and Other Formations*) implies a more advanced state of treatment technology than is currently available, especially in regard to

dissolved organic compounds and radioactive materials. To attempt to create a mechanism for approving such discharges as "safe" is therefore premature, unnecessary, and likely to lead to unintentional but potentially extremely harmful contamination of Basin waters.

The regulations should therefore expressly forbid transportation of oil and gas waste fluids to any site in the Basin and also forbid storage of such materials, since regularly employed "storage" mechanisms do not provide adequate containment. Materials leaching from landfills or spilled during transport will invariably flow under the pull of gravity down to surface or ground waters. Some of these materials, including the radioactive elements, can, in very small concentrations, cause serious, sometimes life-threatening illness, including tissue and organ damage, neurological disorders, leukemia and solid tumors, miscarriages, stillbirth, and congenital malformations.[15] Worse, in areas that have high background loads of radiation or heavy metals or that have suffered previous toxic contamination, the effects of additional contamination may be cumulative or, worse, synergistic.

Moreover, since spreading fracking waste on roads or on fields is hydrologically equivalent to pouring toxins into surface and ground water, such spreading should also be expressly prohibited in the revised regulations, as is addressed in the attached report, case study, original research, and supporting materials provided by Paul Rubin, hydrogeologist and President of HydroQuest (HydroQuestBrineSpreadingReportwithAddendas-20180329).pdf). These materials focus on the practice of disposing of fracking waste or other oil and gas waste via spreading on roads, fields, and recreation areas, which is allowed or appears to be allowed in at least two Basin states (PA and NY) through permits called "Beneficial Use Determinations" ("BUDs"). While Warren County, the site of the HydroQuest case study, is located in northwestern PA, outside of the Delaware River Basin, its use as a case study area is justified because it is representative of geologic and hydrologic conditions present throughout PA and the northeastern United States where contaminant transport outward from brine disposal sites will adversely impact surface and groundwater resources.

Based on the priority of protecting drinking water resources, Catskill Mountainkeeper also opposes those portions of the proposed regulations that would allow the withdrawal of water from the Delaware River Basin for fracking or any industrial purpose.

Finally, we address the critical issue of the Commission's staffing and resources. To insure that the environment of the Basin and the health of its residents are protected, and to minimize costs of management and enforcement, clear prohibitions should be enacted on not only fracking activities but also the introduction or handling of fracking waste. The Commission can – and must – refrain from finalizing any proposed regulatory program and from processing and issuing permits unless and until questions about resources to enforce adopted regulations have been fully

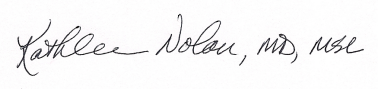
[15] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction), 5th ed. (accessed online 3/30/2018 at http://concernedhealthny.org/compendium): see Public health effects, measured directly, pp. 148ff

considered and addressed. The same commitment should be made with respect to financial assurances, bonding requirements, and any other measures that the DRBC may identify as necessary for the responsible implementation of these proposed regulations.

In summary, Catskill Mountainkeeper supports the Delaware River Basin's proposed ban on fracking activities in the Delaware River Basin, and we urge the Commission also to ban the importation, storage, or disposal of fracking waste, as well as waste from conventional oil and gas activities, in the Delaware River Basin, and to ban the use of Basin waters for fracking or any industrial purpose. Taking these actions now will continue a bright future for the waters of the Basin and the health and economy of its citizens.

Thank you for your careful attention to these comments.

Sincerely,



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Disposal of Oil & Gas Field Produced Waters: A Hydrologic Case Study of PA Brine Spreading Practice

by Paul A. Rubin 3-29-18

Introduction

Surface disposal of chemically-laden produced waters on roads, fields, or other land areas will lead to degradation of surface and groundwater resources. Assuming that produced brine use is ultimately allowed in the State of Pennsylvania, such brine should be treated to concentration levels equal to or below state and federal water quality standards, whichever is stricter. Preferably, surface disposal of produced water should be prohibited. At this time, PA DEP has a set of Operating Requirements that, if met, provide an approval procedure to dispose of poorly or untreated produced water on road and land surfaces. This report examines serious flaws in PA DEP guidance and enforcement, using an area in northwestern PA as a case study to illustrate why spreading of produced waters anywhere in PA (e.g., Warren County, Delaware River Basin, Susquehanna River Basin), or elsewhere, should be banned. This detailed study documents that regulations designed to "*protect and conserve water resources*" cannot be relied upon when permits are and can be obtained that authorize the disposal and dispersal of contaminated wastewater into waterways and aquifers. The principles discussed here apply equally to produced wastewaters, regardless of whether they are derived from unfracked or fracked conventional or unconventional wells.

This case study demonstrates that existing, in-situ, regulations regarding spreading of produced waters from conventional oil and gas wells, as is readily approved by PA DEP, exacerbates pollutant transport into waters of the Commonwealth. PA DEP documents establish their knowledge and concern relative to road salting practices and water quality degradation. Yet, their approvals to spread chemically-concentrated produced water that will only further degrade state water resources is disjunct from their own published environmental findings. Approvals require limited and infrequent chemical assessment of produced waters and fail to adequately consider off-road transport and fate of numerous pollutants. Furthermore, Operating Requirements fail to consider the provenance of shales and interbedded shales and sandstones that are geologically linked and exhibit similar geochemical signatures (e.g., black shales provide hydrocarbon-rich products that migrated upward into overlying sandstone reservoirs). The physical relationship between source rocks and reservoir rocks does little to alter contaminants in produced brine waters.

Spreading of brine-rich produced waters on road and land surfaces serves to worsen the already well-documented mobilization of road salt derived surface and groundwater contamination.

Knowledge of this background information and individual PA DEP Operating Requirements is critical when contemplating special regulations being proposed by the Delaware River Basin Commission (DRBC). The stated purpose of Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations (Section 440.1) is:

> "*The purpose of this part is to protect and conserve the water resources of the Delaware River Basin. To effectuate this purpose, this section establishes standards, requirements, conditions and restrictions to prevent or reduce depletion and degradation of surface and groundwater resources and to promote sound practices of water resource management*."

Reference to Section 440.5(b) of the DRBC Subchapter B - Special Regulations reveals that certain approvals relative to the importation and discharge of produced water and Centralized Waste Treatment (CWT) wastewater may not forego cited criteria:

> "*… except in accordance with an approval in the form of a docket issued by the Commission to the owner or operator of the wastewater treatment facility pursuant to Section 3.8* ***OR*** *in accordance with a state permit issued pursuant to a duly adopted administrative agreement between the Commission and the host state*." (emphasis added)

As discussed below using this case study as an example of the poor quality regulations, limited oversight, and flawed hydrologic concepts form the foundation of existing PA regulation of produced water spreading, it would not be prudent to have any non-specific means of obtaining approvals from either the State of Pennsylvania or the DRBC. Instead, it should be recognized that there is no sound rationale for importing, exporting, treating, or disposing of produced waters (or solid oil and gas field wastes) within the Delaware River Basin or anywhere within the state of PA. All potential adverse water quality issues may be judiciously addressed by simply banning all forms of oil and gas industry wastes from the Delaware River Basin. This is the best means of " *… avoiding injury to the waters of the Basin …* and *… protecting and conserving the water resources of the Delaware River Basin*."

Natural Salt Spreading on Roads: An Old Practice with Related Water Contamination - The Forerunner of Produced Brine Spreading

The use of rock salt as a deicing agent is well-established, but not without associated adverse environmental impacts. Water quality degradation attendant to spreading rock salt on roads has been recognized as a major environmental issue since the 1950s, or before (e.g., Transportation

Research Board, 1991). Contamination of streams and private and public water supply wells from off-road transport of rock salt was well documented and known to highway departments and regulating agencies long before the flawed concept of dispersing chemically-laden produced water on roads and fields was coined by the oil and gas industry and regulating agencies (e.g., PA DEP) as a "*beneficial use*". Similarly, recent water quality studies solidly document adverse environmental impacts associated with road salting, including surface and groundwater contamination (e.g., Fortin Consulting, 2014; Minnesota Pollution Control Agency, ~ 2012; U.S. EPA, 2009; U.S. EPA, 2010; Environment Canada, 2013; PA DEP and SPC, 2013). Fortin, for example, addressed chloride in salt as a toxic pollutant that accumulates over time in waters and documents thirty-eight stream reaches, lakes and wetlands that are impaired for aquatic life due to high concentrations of chloride. Similarly, Environment Canada (2013) documents 16 case study examples of water quality degradation and management efforts stemming from road salting, thereby documenting the multi-national nature of the environmental problem. Clearly, documentation of adverse impacts to surface and groundwater quality, as well as to fauna and flora, from brine solutions was established long ago - far before the gas and oil industry and their regulators advanced the concept of disposing of produced water containing brine plus additional contaminants (as discussed below) and therefore worse for water quality on roadways and land under the guise of a "*beneficial use*".

U.S. EPA (2009) summarizes water quality concerns associated with road salt use:

> "*Surface water and ground water quality problems resulting from road salt use are causing concern among both state and local governments. Salt contributes to increased chloride levels in ground water through infiltration of runoff from roadways[2]. Also, if runoff containing road salt reaches a stormwater injection well, it can provide a concentrated input of chloride to ground water. Unlike other contaminants, such as heavy metals or hydrocarbons, chloride is not naturally removed from water as it travels through soil and sediments and moves towards the water table. Once in the ground water, it may remain for a long time if ground water velocity is slow and it is not flushed away. Chloride may also be discharged from ground water into surface water. Direct input of salt into surface water from runoff is also problematic[3]. Increasing chloride concentrations have been observed over the last few decades in streams, lakes, and ponds in northern climates that receive significant snowfall[4]. Reservoirs and other drinking water supplies near treated highways and salt storage sites are especially susceptible to contamination. Thus, regardless of the path that the runoff takes, salt poses a water quality problem. The best chance for long term mitigation is to reduce the application of salt to road surfaces in a manner that does not jeopardize public safety on the roads*."

The PA DEP and Southwestern Pennsylvania Commission Water Resource Center (2013) also acknowledge the need to reduce chlorides in the environment in winter maintenance. They state:

> "*Along with the increased use of salt, levels of chloride in surface and groundwater and associated impacts will also increase. Negative impacts have proven to be associated with the use of snow and ice control materials and have become a real concern in some states. … Due to the amounts of deicers used in Pennsylvania during the winter months, it is probable that impairments may exist. … Chloride (Cl^-) is highly soluble, very mobile, and its density allows for it to settle to the bottom of a waterbody. Chloride is toxic to aquatic life at levels above 230 mg/l. There is no natural process by which chlorides are broken down, metabolized or taken up by vegetation. ... Chloride remains in a solution and is not subject to any significant natural removal methods. Chlorides are toxic to aquatic life at high concentrations. ... Chlorides do not degrade in the environment; instead they accumulate and therefore infiltration is not a good practice for addressing chloride impairments specifically.* ***Almost all chloride applied to roads, sidewalks and parking lots will reach our lakes and streams via runoff or infiltration.***" [emphasis added]

The chloride concentration of produced brine spread on roads in Warren County, PA extends upwards of 73,000 mg/L, some 317 times greater than the concentration that is toxic to aquatic life.

PA DEP identifies salt application impacts from roadways as:

- Air Quality,
- Aquatic/Terrestrial Flora,
- Soil Quality, and
- Water Quality.

Furthermore, PA DEP and SPC provide a boxed quote from the MN Pollution Control Agency (below). This is followed with a discussion of BMPs to reduce chlorides in accordance with Total Maximum Daily Load (TMDL) plans. Off-road transport of chlorides and other chemicals into waterways and groundwater degrades water quality, regardless of whether application is associated with winter deicing or for dust suppression at other times of the year.

> "*It takes only one teaspoon of road salt to permanently pollute 5 gallons of water. Once in the water, there is no way to remove the chloride, and at high concentrations, chloride can harm fish and plant life. Less is more when it comes to applying road salt*."

Spreading of Oil & Gas Field Produced Brines on Roads - An Extension of a Practice Known to Contaminate Surface and Groundwater Resources

There is no sound hydrologic basis for believing that spreading produced waters, which are chemically worse than historic rock salt spreading, will not result in increased off-road water quality degradation. This report uses a Warren County, PA (Farmington Township) example to examine the flawed underpinnings of the PA DEP Operating Requirements that form the basis of brine spreading approvals, with emphasis on disposal of conventional well produced waters representative of what might potentially be spread on roads anywhere in PA, including in the Delaware and Susquehanna river basins. **Thus, a Farmington Township case study is used as an analogue to address potential environmental degradation that may occur anywhere in the state of Pennsylvania, and beyond, should road spreading of conventional produced water continue to be permitted.** Spreading of chemically-laden produced waters needlessly jeopardizes surface and groundwater quality. This practice should be stopped immediately.

Hydrologically, it is not possible to regulate the spreading of chemically-laden production brines in a manner that will preclude off-road transport to surface and groundwater resources. In Pennsylvania, the Department of Environmental Protection (PA DEP) regulates the spreading of produced waters on dirt roads (PA DEP, 2015), which they view as "*a beneficial use of the brine*." Because of the potential for contaminants from brine-rich produced water from non-shale formations to leach into surface or ground waters, spreading brine on dirt roads for dust suppression and road stabilization requires DEP's approval and must follow a specific plan.

PA DEP's operating requirements purport to be designed to "*minimize the environmental impact*" of off-road surface and groundwater contamination. The underlying guideline means of achieving this can be summarized as 1) don't spread brine on wet roads, during rain, or when rain is imminent, 2) don't apply on road sections with grades in excess of 10 percent, 3) separate free oil from the brine before spreading, 4) don't spread at rates and frequencies above what is needed to suppress dust and stabilize roads, 5) control the rate and frequency of application to prevent brine from flowing into roadside ditches, waterways, waterbodies, and groundwater, and 6) don't apply brine within 150 feet of a stream, creek, lake or other body of water.

Application approval requires a set of informational details including a signed approval statement from the municipality, identification of the geologic formation from which the brine is produced, and a representative chemical analysis of the brine for the following parameters: calcium, sodium, chloride, magnesium and total dissolved solids. The list does not include any analyses of hydrocarbons or multiple toxic chemical additives that may also be present. [Note: A draft Road Spreading of Brine Approval form (PA DEP, not dated) states that a chemical analysis of the brine should include total dissolved solids, chloride, sodium, calcium, pH, iron, barium, lead, sulfate, oil and grease, benzene, ethylbenzene, toluene, and xylene. The removal of this limited list of

hydrocarbon parameters from the brine spreading approval list is telling, as is the omission of testing for Naturally Occurring Radioactive Material (NORM).] From a hydrologic perspective, these operating requirements will not prevent the off-road transport of chemically-laden wastewater (i.e., produced water) to surface and groundwater sources.

PA DEP operating requirements specifically preclude use of produced water brines for dust suppression and road stabilization from unconventional wells in shale formations (§ 78a.70). Yet, as documented here using example chemical data from conventional geologic formations (i.e., Bradford Group sandstones), the risk of potential surface and groundwater contamination is equal to or greater than that of the Marcellus shale. Oil and gas producing formations typically have high salinity values, heavy metals (e.g., barium, strontium), and volatile organic chemicals - including benzene which is a known carcinogen. Some of these Operating Requirements are examined in detail below.

PA DEP Brine Spreading Operating Requirements (OR)

The PA Department of Environmental Protection has a number of Operating Requirements that it deems sufficient for the "*safe*" application of brine on unpaved roads. Operating Requirements 2, 3, 4, 5, 7 and 8 will be discussed here.

Operating Requirement 2: Application Rate to Avoid Contact with PA Water Resources

This Operating Requirement states:

> "*The brine may only be applied at a rate and frequency necessary to suppress dust and stabilize the road. The rate and frequency of application must be controlled to prevent the brine from flowing or running off into roadside ditches, streams, creeks, lakes and other bodies of water or infiltrating to groundwater*."

While the underlying concept behind this operating requirement makes sense, it fails to consider the hydrologic cycle recognized by hydrologists for well over a century. Essentially, rain water falls to the earth's surface and then either runs off into down-gradient surface water receptors (e.g., roadside ditches, streams, creeks, lakes, reservoirs, wetlands, oceans) or infiltrates into underlying sediments and bedrock. Under both scenarios, the water moves down-gradient from where it falls and eventually returns to clouds via a variety of mechanisms (e.g., evapotranspiration, evaporation, sublimation), where it renews the cyclic process again. Thus, any water, brine and soluble chemicals spread on roads must also follow this hydrologic process. If they did not, and roadways somehow functioned as isolated elongate sponges with impermeable bases and walls (e.g., like long fish tanks), all rain water and brine incident to them would stay within the footprint of roads and would result in an increasingly upward rising water column or mound. Clearly, creation of this "hypothetically" bounded wall of brine-rich water does not and cannot exist. Brines, rain

water, and produced water contaminants must move down-gradient into surface water bodies and groundwater flow regimes, as can be seen in Figures 1 and 2 below. Whether this occurs on the date of brine spreading or following rain or snowmelt events, unless some filtering event intervenes, it is a hydrologic certainty that down-gradient contamination will occur.

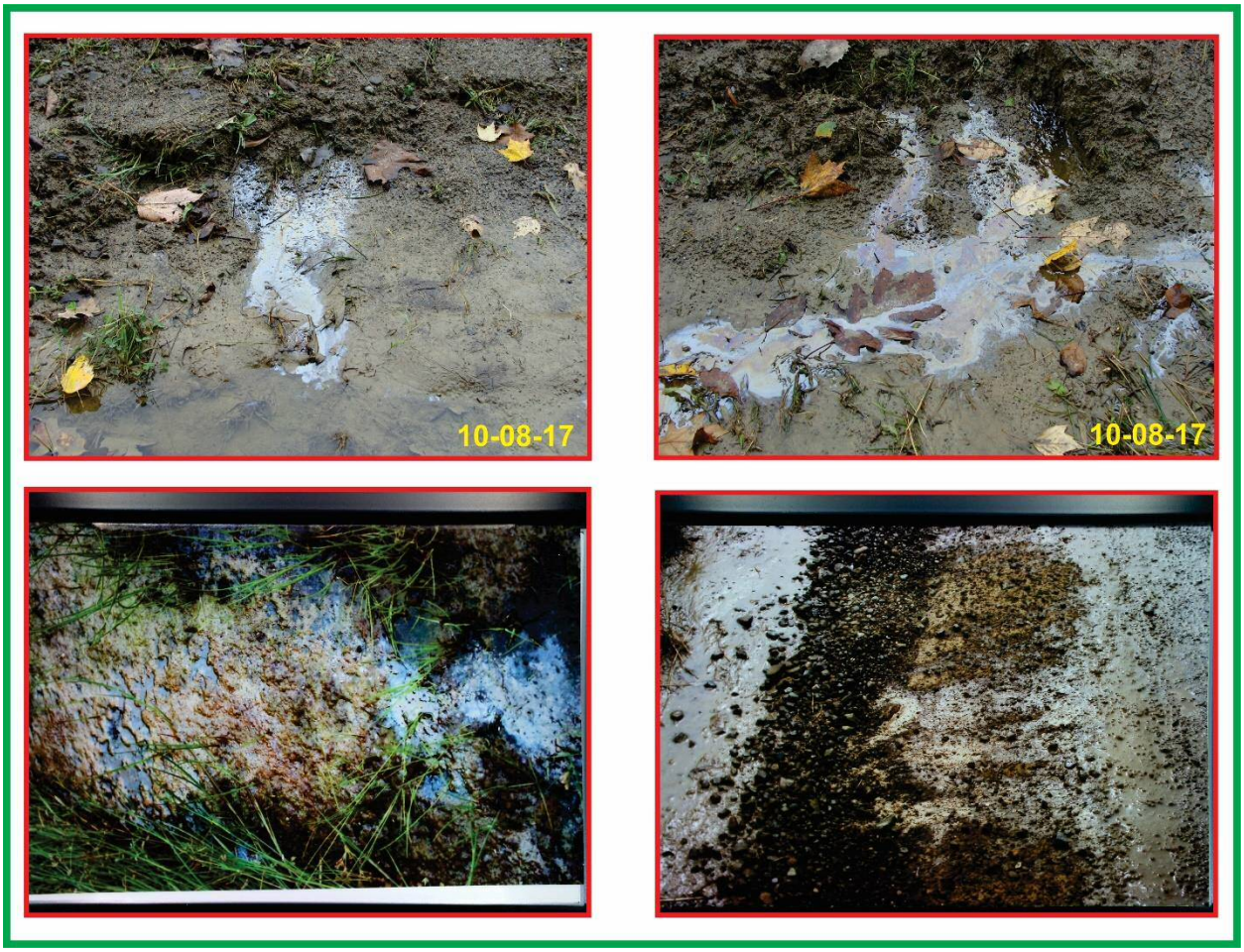

Figure 1. Sediment discoloration along Warren County, PA roadways where brine spreading has occurred. The bottom right photo shows brine flowing from a road surface into a drainage ditch.

Natural subsurface filtering of brine does not occur because salts are almost infinitely soluble. This is why there are numerous contaminated groundwater cases down-gradient of salt and sand/salt piles. Thus, the assumption underlying this operating requirement is based on flawed reasoning. Brine spread contaminants will move outward and downward from roads at rates and frequencies controlled by well-documented hydrologic factors (e.g., hydraulic gradient, soil and bedrock permeability, effective porosity, chemical load), thereby posing a salinization and contaminant threat to headwater watersheds. This will result in contamination of state water resources.

Numerous authors have identified concerns about the potential for compromising drinking water quality near areas of oil and gas development (e.g., Kreuzer et al., 2018; Burgos et al., 2015; Johnson et al., 2015; Rena, 2008). Johnson et al. (2015) warn and document that produced waters associated with active and legacy conventional Upper Devonian oil and gas wells may and have increased total dissolved solids (TDS) in groundwater and streams. They cite the risk to surface and groundwater quality via improper disposal of drilling fluids or produced waters and provide a chemical means of discriminating between road salt sources and natural brine and/or produced water from oil and gas wells. Risk to surface and groundwater quality stemming from off-road transport of produced water brines and chemicals has been recognized and well-studied for over half a century (e.g., U.S. EPA, 1987). The U. S. EPA study found that a variety of pollutants can be released to both surface and groundwaters as a result of the production of oil and gas. These pollutants include high concentrations of total dissolved solids and chloride. This study details disastrous wastewater disposal practices, many by permit, that have or will degrade surface and groundwater quality for decades or centuries to come. Information obtained from this study were to be used, in part, for determining water quality management requirements, presumably key data used in formulating current PA DEP road spreading operating requirements. PA DEP Operating Requirements, DRBC regulations, and any kind of waste disposal permit cannot stop naturally-occurring hydrologic processes that mobilize and transport contaminants away from road surfaces.

Figure 2. Runoff of produced brine into drainage ditches in Warren County, PA.

Operating Requirements 3 and 8: Recommended Spreading Rates & Weather Conditions

Operating Requirement 3 provides recommended brine spreading rates, starting with a rate of up to one-half gallon per square yard and becoming less thereafter. Presumably, the basis for the stated rates is to insure contaminant runoff does not occur at the time of waste spreading, instead delaying off-road transport into surface and groundwater resources following subsequent rain and/or snowmelt events. Reference to Figures 1 and 2 above provide evidence that Operating Requirements are of little value when they are not adhered to, or if rain events occur at any time after brine application. Clearly, excessive brine applications, as currently conducted in Warren County PA, often involving at least four passes per road per day are sufficient to saturate road surfaces with resultant chemical runoff into waters of the Commonwealth. In addition, brine spreading has occurred both during times of precipitation and when it was pending (Lawson, pers. Comm.). This is in violation of PA DEP Operating Requirement 8.

Moreover, since there is no natural subsurface filtering of ionized salts and no documented filtering of most other contaminants in produced water, there is no sound basis for believing that contamination will be reduced by reduced rates of spreading or absence of rain.

The concept of following "*Recommended spreading rates*" as put forth in Operating Requirement 3 is equally flawed. Brine spreading contaminants will eventually be transported to surface and groundwater resources (e.g., creeks and wells). A comparable analogy would be to slowly apply cyanide-rich brine above one's water well. Clearly, neither the rate nor the frequency of applying a contaminant source above water resources will provide a "*safe*" water quality situation. As discussed above, rates of contaminant arrival are a function of hydrologic factors and time. There are no "*safe*" contaminant spreading rates.

Operating Requirement 4: Only Production or Treated Brines May be Used

This Operating Requirement states:

> "*Only production or treated brines may be used. The use of brine from Marcellus and other non-conventional shale formations is not applicable for road spreading. The use of drilling, fracing, or plugging fluids or production brines mixed with well servicing or treatment fluids, except surfactants, is prohibited. Free oil must be separated from the brine before spreading*."

This operating requirement provides no chemical thresholds for evaluating chemical components of brine and no "*acceptable*" contaminant concentrations on a parameter-specific basis. Yet, it clearly states that brine from Marcellus and other non-conventional shale formations is not applicable for road spreading. PA DEP emphasizes that brine produced from any shale formation

is not applicable for road-spreading. These shale formations include but are not limited to Marcellus, Rhinestreet, Burket, Geneseo, Mandata, Utica, Huron, Dunkirk, Pipe Creek, Middlesex, Needmore, Girard, and Cabot Head (PA DEP, not dated).

Presumably, then, the PA DEP has evaluated the chemistry of Marcellus produced waters and found it to be unacceptable for brine spreading. Using a January 14, 2016 PA DEP Brine Spreading Plan Review (Approval No. NW1716; PA DEP 1-14-16) as a representative example of DEP's evaluation particulars, their approval review appears to be based on five brine indicator parameters: chloride, total dissolved solids, calcium, magnesium and sodium.

The concentration values for Approval No. NW1716 (PA DEP 4-06-16) are provided on Table 1 below (page 16) for the Hydro Transport ALS Environmental Sample. Additional insight into the source of brine waters considered acceptable for PA DEP approval are found on DEP's April 6, 2016 Approval No. NW5916 issued to Hansen Services. This approval contains the same Operating Requirements. It also provides a listing of geologic formations from which brine waters are produced. It specifically states that all formations are from Upper Devonian Bradford Group sandstone formations including:

- Warren 1st, 2nd, 3rd (Warren First sandstone top marks the base of the Chadakoin)
- Glade/Queen
- Clarendon
- Balltown/Cherry Grove
- Cooper/Klondike

In western PA, the Bradford Group is depicted on PA geologic columns as being stratigraphically above the underlying Middle Devonian Marcellus Shale and below the Upper Devonian Chadakoin Formation. Dodge (Bedrock Lithostratigraphy of Warren County, Pennsylvania Guidebook paper; 1992) states that the Chadakoin Formation averages about 450 feet thick in Warren County and consists of interbedded greenish-gray to light-gray or reddish-purple-gray shale, with some very fine- to fine-grained, light-greenish-gray to light-gray sandstone. Dodge identifies the primary oil-producing strata within the Bradford Group as including the Glade (or Queen), Clarendon, Balltown, Cherry Grove, Cooper, Klondike, and Deerlick sandstones. Oil saturations in Bradford Group reservoirs range from 5 to 45 percent, averaging about 20 to 25 percent (Harper, 1992). It is therefore likely that Bradford Group brines spread on Warren County roads include a hydrocarbon contaminant component. This is borne out in a 1-07-16 brine sample submitted for analysis by Hansen Services (1,3,5-trimethylbenzene: 59.3 ug/L; 1,2,4-trimethylbenzene: 136 ug/l; benzene: 2,090 ug/L; toluene: 1,870 ug/L; ethylbenzene: 90.2 ug/L; xylenes: 957 ug/L; naphthalene: 10.2 ug/L; 3&4 methylphenol: 124 ug/L; 2-methylphenol: 101 ug/L). Therefore, under its current Operating Requirements, PA DEP approves the spreading of oil field brines laced with hydrocarbons. Hydrocarbon contaminants were detected in a Dalyrmple Road brine sample spread and collected on 8-28-17 (acetone: 3,840 ug/L; benzene: 12.6 ug/L; 2-

Butanone (MEK): 798 ug/L; 2-hexanone: 36.1 ug/L; toluene: 2.6 ug/L; xylenes: 7.3 ug/L), documenting spreading of multiple contaminants inclusive of benzene (a known carcinogen).

The high percentage of oil saturation present in Bradford Group produced waters may make its contaminant potential greater than those from the Marcellus Shale. It is interesting to note that PA DEP brine spreading approval is based solely on chemical analysis of sodium, calcium, magnesium, chloride and total dissolved solids, and no hydrocarbon analyses (not even a total organic carbon analysis). Apparently, there are no concentration limits specific to these parameters, just the requirement that they not be derived from the Marcellus Shale and other non-conventional shale formations.

As stated above, PA DEP Operating Requirement No. 4 states that brine produced from any shale formation is not applicable for road-spreading. This broad limitation becomes problematic when evaluating which geologic formations do not contain shale and connate brine waters within them and are exploited for gas and/or oil production. As documented above, produced water from the Bradford Group in Warren County, PA has been approved for road spreading. It is beneficial to examine another location in PA from which produced water might originate that could potentially be approved for road spreading. In this second location, a number of production intervals occur within the Lock Haven Formation which has a significant shale component. The lower portion of the Lock Haven Formation includes Elk Group sandstones overlain by Bradford Group sandstones.

Laughrey et al. (2004) discuss the Council Run gas field situated in north-central Pennsylvania (Centre and Clinton counties). Any brine produced from this gas field would, most likely, be considered for brine spreading because it would be produced from four principal reservoir sandstone formations and not shale formations. The authors identify the gas reservoirs within Upper Devonian sandstones of the Lock Haven and Catskill formations. Sandstones of the Lock Haven Formation that are the most prolific producers are the Fifth Elk, Third Bradford, the basal Bradford and various Elk sandstones. Faill et al. (1977) and Laughrey et al. (2004, by reference and detailed description) define the Lock Haven Formation as gray, brown, and green interbedded shales, mudstones, siltstones, and sandstones that overlie the Brallier Formation and underlie the red beds of the Catskill Formation.

It is particularly important to recognize that Laughrey et al. characterize the potential gas source rocks as the underlying Marcellus shale formation and Burket member of the Harrell Formation. Recall, as discussed above, a draft PA DEP Request for Road-Spreading of Brine Plan Approval form specifically identifies the Burket black shale as a geologic formation from which produced brine is not applicable for road-spreading (PA DEP, not dated).

Specifically, Laughrey et al. state:

> "*Potential source rocks in the study area include the Burket Member of the Upper Devonian Harrell Formation, the Middle Devonian Marcellus Formation, and the Upper Ordovician Utica Shale (Figure 2). These are the only rocks in the region with sufficient total organic carbon to have generated commercial quantities of hydrocarbons (Figure 12). Black shales of the Burket and Marcellus (Devonian) are the likely source of the hydrocarbons produced from the Upper Devonian sandstones at Council Run field*."
>
> "*Petroleum expelled from the Devonian source rocks* (Marcellus and Burket black shales) *migrated through* (overlying) *permeable beds in the Upper Devonian Brallier Formation between 320 and 290 Ma and accumulated in the sandstones of the Lock Haven and Catskill formations. Dispersive migration paths were probably both lateral and vertical (Mann et al., 1997)*."
>
> "*We interpret the critical moment at Council Run field, i.e., that point in time when the generation-migration-accumulation of most hydrocarbons in the* ***Marcellus/Burket–Lock Haven/Catskill petroleum system*** *took place, as having occurred between 260 and 240 Ma, when most of the oil in the petroleum system was cracked to gas*." (emphasis added)

Thus, Laughrey et al. (2004) determined that Lock Haven gas producing zones stratigraphically above the Marcellus and Burket black shales are part of the same petroleum system. It also follows, then, that Lock Haven produced water has almost certainly been in contact with Lock Haven shales since most producing wells in the Council Run field are multizone completions and exhibit similar geochemical signatures as the underlying Marcellus and Burket black shale source rocks. As such, spreading of Lock Haven produced waters may be little different from spreading produced waters from the Marcellus shale. The work of Laughrey et al. and the chemical data presented on Table 1 further bear this out. Recognizing these factors, it is difficult to justify road spreading approval of Lock Haven or other similar production brines that originate from similar geologic settings and exhibit similar geochemical signatures.

Major chemical components present in produced waters have been identified by numerous researchers (e.g., Johnson et al., 2015; Vengosh et al., 2015 & 2017). Wastewater produced from both conventional and unconventional oil and gas wells contain a variety of contaminants of concern including salts, metals, NORM, and both reservoir-derived and anthropogenic organic compounds (e.g., Warner et al., 2013; Burgos et al., 2015). NORMs sometimes occur at very high concentrations, including in brines from conventional wells. Elevated concentrations of strontium, barium, and radium have all been detected in flowback and produced waters from unconventional Marcellus Shale gas wells, in CWT plant effluents, and in river sediments downstream of CWT plants (Burgos et al., 2015). Laughrey et al.'s (2004) determination that hydrocarbons in the Marcellus/Burket-Lock Haven/Catskill petroleum system are geochemically related further

establishes the likely multi-formational presence of NORMs. The dispersal of radioactive water via road and land spreading practices has not been addressed in the permit approval process. This is a significant omission.

Other authors have also identified NORMs as an environmental threat. Sookdeo (2003), for example, discusses strategies for minimizing impacts on the environment in Trinidad and Tobago where produced water is the single largest waste stream by volume within oil and gas field operations. He identifies the constituents of greatest environmental concern as chlorides, hydrocarbons, heavy metals, radionuclides, treatment/production chemicals, and dissolved solids.

A number of authors review methods to dispose oil and gas field waste. Veil (2002), for example, identifies assorted methods of disposing of drilling wastes (drilling fluids and drill cuttings), including land spreading and land farming. Veil lists current standards for road spreading that often include regulatory restrictions placed on chemical constituents of wastes (e.g., chlorides, TPH), application rates, and the slope of the land. He suggests that substitution of some of the key components of drilling fluids with new, more environmentally friendly products could reduce mass loadings to the environment. The chemistry of produced waters identified by numerous authors establishes that chemical loading remains as an environmental problem.

Operating Requirement 4 precludes the use of brine from Marcellus and other non-conventional shale formation from road spreading. Logically, examination of the chemical concentrations of PA DEP's five chemical "*approval*" parameters should permit characterization of concentrations that are too high and, thus, not suitable for brine spreading approval. This can readily be accomplished by examination of chemical work published by Johnson et al. (2015). As part of their chemical work, these authors culled through the literature for published data on the chemistry of Marcellus Shale produced waters. Table 1 provides the fruit of their analysis, presenting ranges and average concentrations of Marcellus Shale produced water. This table also provides chemical data on Bradford Group brines provided by Hansen Services, Hydro Transport and other Bradford Group brine producers. This data includes the five parameters required by PA DEP for permit approval (bolded in red). It appears that brine wastewater is collected from well sites and disposed of directly on county roads, absent any treatment whatsoever. This waste disposal technique jeopardizes the water quality of surface and groundwater resources and ignores treatment considerations (e.g., Baudendistel et al., 2015; Geza et al., 2013; Hum et al., 2005; Hussain et al., 2014; Lawrence et al., 1993 & 1995; Sookdeo, 2003; Balch et al., 2014; Silva et al., 2017; Oetjen et al., 2017).

Table 1 also includes analyses of two brine samples collected from Warren County roads soon after application, one from Dalyrmple Road and one from Old State Road. These applied brine samples were collected by Bryce Payne on 8-28-17. The locations of these samples are depicted as green hexagons labeled A and B on Figures 3 and 4 of attached Addendum 1. Chemically, based on PA DEP indicator parameters, they are similar to the Hansen and other Bradford

Formation samples, as well as Marcellus Shale samples (inclusive of Ristau and Allen brine samples, 2016). Comparison of chemical concentrations for the five PA DEP brine parameters (Na, Ca, Mg, Cl, TDS) for Marcellus Shale and Bradford Group sandstones reveals that there are NO significant chemical differences, perhaps with the exception of multiple hydrocarbons from Bradford Group oil producers. Approved concentrations of chloride in Bradford formation conventional well produced waters (Table 1 below: to at least 73,000 mg/L) are approximately 21 times the chloride concentration in seawater. **Essentially, the concentrations of brine parameters in Marcellus Shale produced water that PA DEP Operating Requirements state are not applicable for road spreading are matched or exceeded by Bradford Group produced water chemistry concentrations. Based on chemical comparison of Marcellus and Bradford Group brines, there is no chemical/water quality basis for spreading contaminant-rich oil and gas field wastewater from either group where they will flow downward and degrade vulnerable surface and groundwater resources.**

Water Quality Parameters for Produced Water Sources (mg/L)								
Source	**TDS***	Ba	**Ca***	**Mg***	**Na***	Sr	**Cl***	Br
Marcellus Fm Samples								
Published Marcellus Shale Produced Water Range - Johnson et al.	44,800 - 211,400	29 - 12,000	2,278 - 20,800	217 - 1,750	11,747 - 49,400	381 - 5,230	29,000 - 159,000	506 - 1,150
Average Marcellus Shale Produced Water - Johnson et al. 2015	**106,390**	2,224	**7,220**	**632**	**24,123**	1,695	**57,447**	511
Bradform Fm Samples								
Old State Rd Brine Sample 8-28-17; Pace	97,920	NA	**8840#**	**1,510**	**24,700**	NA	52,500	<0.1
Dalyrmple Rd Brine Sample 8-28-17; Pace Analytical	NA	3.8	**9,450**	**1,650**	**29,000**	NA	**69,500**	810
Bradford Group Produced Water from Hansen Services 1-07-16	81,860	1.31	NA	**1,270**	23,100	88.1 (dissolved fraction; value hard to read)	52,167	585
Hydro Transport Brine Sample 12-16-12	105,000	NA	**9,810**	**1,670**	**25,700**	NA	**64,300**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-04	**126,000**	NA	**10,200**	**1,660**	**25,900**	NA	**61,000**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-05	**133,000**	NA	**10,400**	**1,530**	**27,900**	NA	**66,000**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-01	**112,000**	NA	**8,430**	**1,310**	23,700	NA	55,000	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-02	86,300	NA	6,340	**1,070**	18,800	NA	42,000	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-03	**144,000**	NA	11,900	**1,800**	**30,700**	NA	**73,000**	NA
J&L Allen Brine Tank Sample 4-13-16	**109,000**	NA	8,270	**1,360**	23,900	NA	52,000	NA

*: PA DEP Brine Spreading Approval Parameter

#: Bolded red values are greater than Marcellus Shale average values.

Table 1

Wastewater Disposal

Burgos et al. (2017) provide an excellent summary of wastewater disposal practice in Pennsylvania:

> "*Depending on the geographic location, Oil & Gas (O&G) wastewaters are typically disposed of into underground injection control (UIC) wells, treated to some extent for in-field reuse, or sent to Centralized Waste Treatment (CWT) plants for treatment and eventual discharge to surface water. Across the U.S., several states, including California, Michigan, Montana, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming, allow produced waters from O&G wells to be discharged to surface water. Recent studies have found that CWT plants often only provide limited treatment of oil and gas wastewater, sometimes resulting in degradation of downstream water quality*."

> "*In August 2010, the Pennsylvania legislature forced new or expanding CWT plants to meet effluent water quality standards of 500 mg/L TDS, 250 mg/L Cl, 10 mg/L Ba, and 10 mg/L Sr. Up until this point, all but one CWT plant in Pennsylvania had only to monitor and report effluent TDS, chloride or osmotic pressure. Eight permitted facilities were listed as exempt from the new TDS standard. In April 2011, the PADEP requested that O&G operators no longer deliver wastewater from unconventional gas wells to CWT plants exempt from the new TDS effluent standard. The net effect of these policy changes dramatically reduced the volume of unconventional O&G wastewater sent to CWT plants and spurred the reuse of produced waters for continued hydraulic fracturing of new wells."*

Apparently, it also spurred the Oil & Gas industry to convince the PA DEP that wastewater disposal directly on the lands of the Commonwealth was a "*beneficial use*". **Reference to chemical concentrations documented on Table 1 raise the question as to why PA DEP would approve and permit the disposal of brine wastewater onto the lands of the Commonwealth in concentrations upward of 300 times effluent water quality standards (i.e., TDS, Cl).** Clearly, untreated wastewater that exceeds CWT plant effluent water quality standards should not be spread on roads or fields where it will enter surface and groundwater.

Operating Requirement 5: Brine Must Not be Applied within 150 Feet of a Waterbody

PA DEP Operating Requirement 5 states:

> "*Brine must not be applied within 150 feet of a stream, creek, lake or other body of water*."

A detailed analysis of the distance between numerous sections of dirt roads where brine has been applied and nearby streams in Farmington Township was conducted. This work is detailed in attached Addendum 1 titled: *Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment*. Figure 4 of Addendum 1 depicts the surface drainage network with 150-foot buffers outward from streams and ponds. Reference to this figure documents numerous locations where brine has been applied within 150 feet of a stream.

Not only is compliance difficult to attain, but the underlying assumption, as with avoiding rain or wet roads, that risk of water contamination can be eliminated by forbidding spreading within a pre-determined distance from observed water resources is also flawed.

Operating Requirement 7: Avoid Brine Spreading on Roads with Grades >10%

PA DEP Operating Requirement 7 states:

> "*Brine must not be placed on sections of road having a grade exceeding 10 percent.*"

Analysis by HydroQuest of numerous road segments in Farmington Township, Warren County where brine applications have been witnessed or viewed soon after application solidly establish that operators either are not aware of road segments with steep grades or simply continue brine application on steep grades. Addendum 1 to this report titled: *Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment* provides a detailed analysis of road grades where brine has been applied. Work conducted for this analysis documents numerous road segments with grades in excess of 10 percent where brine waste haulers have applied contaminant-rich wastewater. This is in violation of PA DEP Operating Requirements.

Again, poor compliance and flawed hydrologic reasoning underlying the Operating Requirement result in the virtual certainty of contamination of surface and groundwater resources, including those that serve as sources of drinking water.

Discussion

Water quality risks associated with brine application in the State of Pennsylvania and other states have long been recognized as an important environmental issue. I have raised many of the concerns addressed in this report previously in a Nov. 15, 2011 technical report titled: *Natural Gas Brine Dispersal on Roadways and the Risk of Surface and Groundwater Contamination (Comments on DEP Permit # WMGR064),* appended as Addendum 2. As established above, brines from gas and oil fields both have high concentrations of numerous chemical contaminants, making land application of either dangerous from a water quality perspective. As such, water

quality/contaminant concerns discussed in the Nov. 15, 2011 report also apply to Bradford Group brines.

All the concerns raised above apply equally to any state in the United States, including Pennsylvania. The PA DEP developed a Fact Sheet that pointedly explains to the public the definition and the potential "*beneficial use*" of brine in the Commonwealth:

> "*Brine is the general term for wastewater produced along with oil or gas; it can be very salty, therefore, injurious to plants and aquatic life."*

If brines can be injurious to plants and aquatic life, it clearly is not prudent to expose Pennsylvania residents to the same chemicals via ingestion and physical contact. From a hydrologic and water quality standpoint, the certain dispersal of brine wastewater chemicals into our waterways, reservoirs, and freshwater aquifers from intentional brine dispersal is analogous to running a small secondary line from an oil tank and slowly dripping its contents onto the ground surface, close to a drinking water well. While it may be difficult to predict exactly when a homeowner's water supply will be permanently degraded, they may be confident in the knowledge that they will soon need to buy bottled water. Hydrologically, the flow dynamics are the same - application of contaminant-laden brines on our roadways will move into our finite water resources and degrade them.

These brines contain salts that are virtually infinitely soluble in water, as well as other chemicals, some of which are toxic and may potentially have serious adverse health impacts. Concentrated and chemically-laden brines should not be discharged into the environment. This is not a beneficial use. Oil and gas well brines need to be properly treated and disposed of.

Conclusion

The use of untreated brine from any geologic formation that has been subject to oil and/or gas production should be banned as brine-rich fluids and chemicals within them pose a direct water quality threat to streams, creeks, rivers, reservoirs, wetlands, lakes, other water bodies and groundwater, including private, public and municipal wells. The underlying concept that procedures (i.e., Operating Requirements) and open-ended regulation wording may be used to prevent brine from entering surface and groundwater is flawed. At some point in time (e.g., spring runoff) brine accumulations on roadways, fields, tracks and other locations used for brine disposal (under the moniker of "beneficial use") will enter and move with surface water and groundwater flow regimes - thereby degrading water quality. As such, brine applications pose a real risk to the health and safety of people, wildlife, ecosystems and the environment.

The land application of oil and gas field brine waters should be ceased immediately, unless it is first treated to meet or exceed all Centralized Waste Treatment plant effluent water quality standards or, state drinking water standards - whichever is stricter.

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by Paul A. Rubin; March 29, 2018

Addendum 1: Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment

Introduction

The Commonwealth of Pennsylvania permits the application of oil and gas well production brine to roads for dust control and stabilization. The Pennsylvania Department of Environmental Protection (DEP) has provided operating requirements regarding the rate and frequency of brine application that, presumably, will afford "*environmental protection*". Their Operating Requirements, as stated in Brine Spreading approvals state:

> "*The rate and frequency of application must be controlled to prevent the brine from flowing or running off into roadside ditches, streams, creeks, lakes and other bodies of water or infiltrating to groundwater*."

Among a number of DEP Operating Requirements (OR), brine spreading approvals state that brine must not be spread on sections of road having a grade exceeding 10 percent (OR No. 7) and must not be applied within 150 feet of a stream, creek, lake or other water body (OR No. 5). Using Farmington Township, PA as an example, this report examines a physical and hydrologic setting where brine has been applied heavily. The February 23, 2018 HydroQuest report titled: *Hydrologic Evaluation of PA DEP Brine Spreading Operating Requirements* addresses the lack of hydrologic foundation available to support the approval of brine spreading on any topographic grades or within watersheds where humans, animals and ecosystems have the potential of ingesting or coming in contact with surface and/or groundwater resources. The findings below were reached to a reasonable degree of scientific certainty.

Percent Grade Analysis

HydroQuest conducted an analysis of the topography and hydrology of a portion of northern Warren County, Farmington Township in northwestern, PA, with emphasis on the slope and percent grade of roads where chemically-laden hydraulic fracturing fluid waste has been spread (i.e., disposed of) on road surfaces. The percentage grade of a road is the slope written as a percent. This slope analysis entailed constructing GIS maps from mosaiced one-meter Digital Elevation Model (DEM) data.

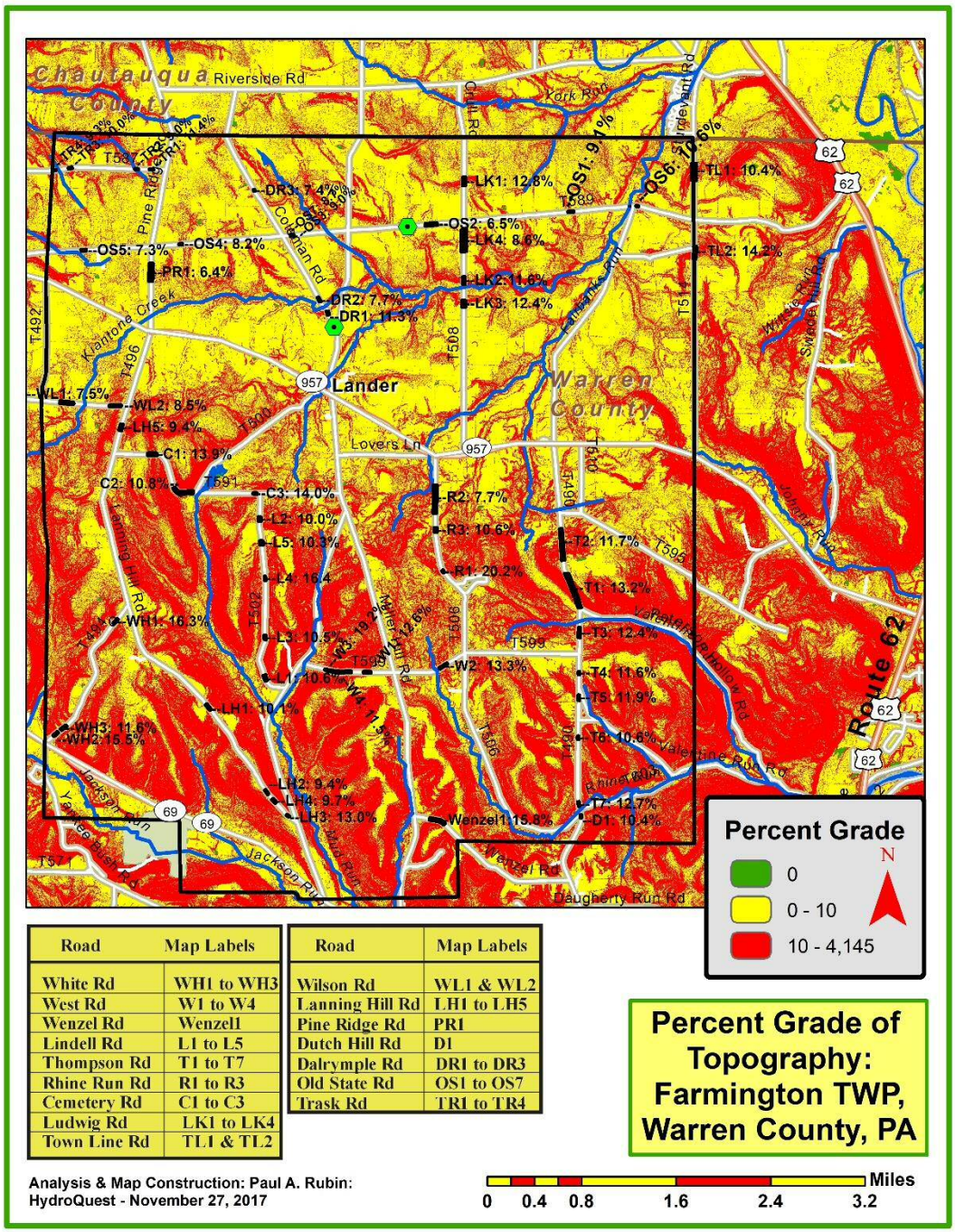
The roads examined were White Road, West Road, Wenzel Road, Lindell Road, Thompson Hill Road, Rhine Run Road, Cemetery Road, Ludwig Road (aka Ludwick Rd.), Wilson Road, Lanning Hill Road, Pine Ridge Road, Dutch Hill Road, Trask Road, Dalrymple Road (aka Coleman Rd.), Old State Road, and Town Line Road. Road nomenclature used follows that depicted on the June 21, 2006 Hass Associates Addressing Services' Farmington Township map. The sources of Digital Elevation Model (DEM) and 2-foot elevation, LiDAR-derived, data are the Pennsylvania Department of Conservation and Natural Resources and the U.S. Geological Survey. Data analysis and map construction were conducted by Paul A. Rubin of HydroQuest.

The percent grade analysis map depicts topographic percent grade broken out into zero percent grade, 0.01 to 10 percent grade, and 10 to 4,145 percent grade (Figure 1). Note that no road in the Township is entirely flat, all roads are shown to have some measurable grade. In addition, more detailed analysis of 55 steep road sections was conducted using higher resolution 2-foot contour map data derived from 2007 Airborne Light Detection and Ranging (LiDAR) Survey data. The locations and percent grade of these road segments are portrayed on Figure 2. The 2-foot contours are not depicted on report maps because the fine contour detail would overwhelm them. Detailed closeup examination of 2-foot contour intervals and distance measurements were conducted while zoomed in on a Geographic Information System (GIS) map base. The values and measurements used to determine slope and percent grade are presented in Tables 1 and 2 below. All elevation and distance values are in feet.

Reference to Figure 2 and the tables establishes that many road segments where brine is applied within Farmington Township exceed a ten percent grade, with at least one measured road segment of 20.2 percent grade. It is important to recognize that while many steep road grade sections documented here equal or exceed the percent grade brine application cutoff value of 10 percent, many road sections in the Township have long steep lengths far in excess of the measured distances documented in Tables 1 and 2.

It is important to recognize that the Operating Requirement value of 10 percent grade has no scientifically valid or defensible empirical basis or foundation. This is an arbitrary percent grade number. Surface and roadside runoff will flow overland at any percent grade in excess of zero. Surface flow outward from salted roads is a well-documented source of surface and groundwater contamination. This is particularly relevant because brine and salt are nearly infinitely soluble in water. Numerous cases of contamination have led municipalities to reduce salting activities proximal to reservoirs and to cover salt and salt/sand storage piles. There is no valid justification for avoiding brine spreading on road grades exceeding 10 percent because brine will be mobilized and will runoff from road surfaces of all grades in adjacent drainageways, if not on the date of application - then on a future date. Brine contaminants may result in adverse environmental impacts (e.g., fishery and ecologic degradation, water quality related impacts to livestock drinking from streams, milk production, aquifer degradation). Land surfaces with low percent grades beyond brined roads have the potential of having high infiltration rates to groundwater, thereby promoting aquifer contamination. Regardless of road grade, disposal of oil and gas industry waste products has the potential of degrading surface and groundwater resources. Figure 2 depicts numerous Farmington Township road sections with percent grades exceeding the PA DEP Operating Requirement value of 10 percent.

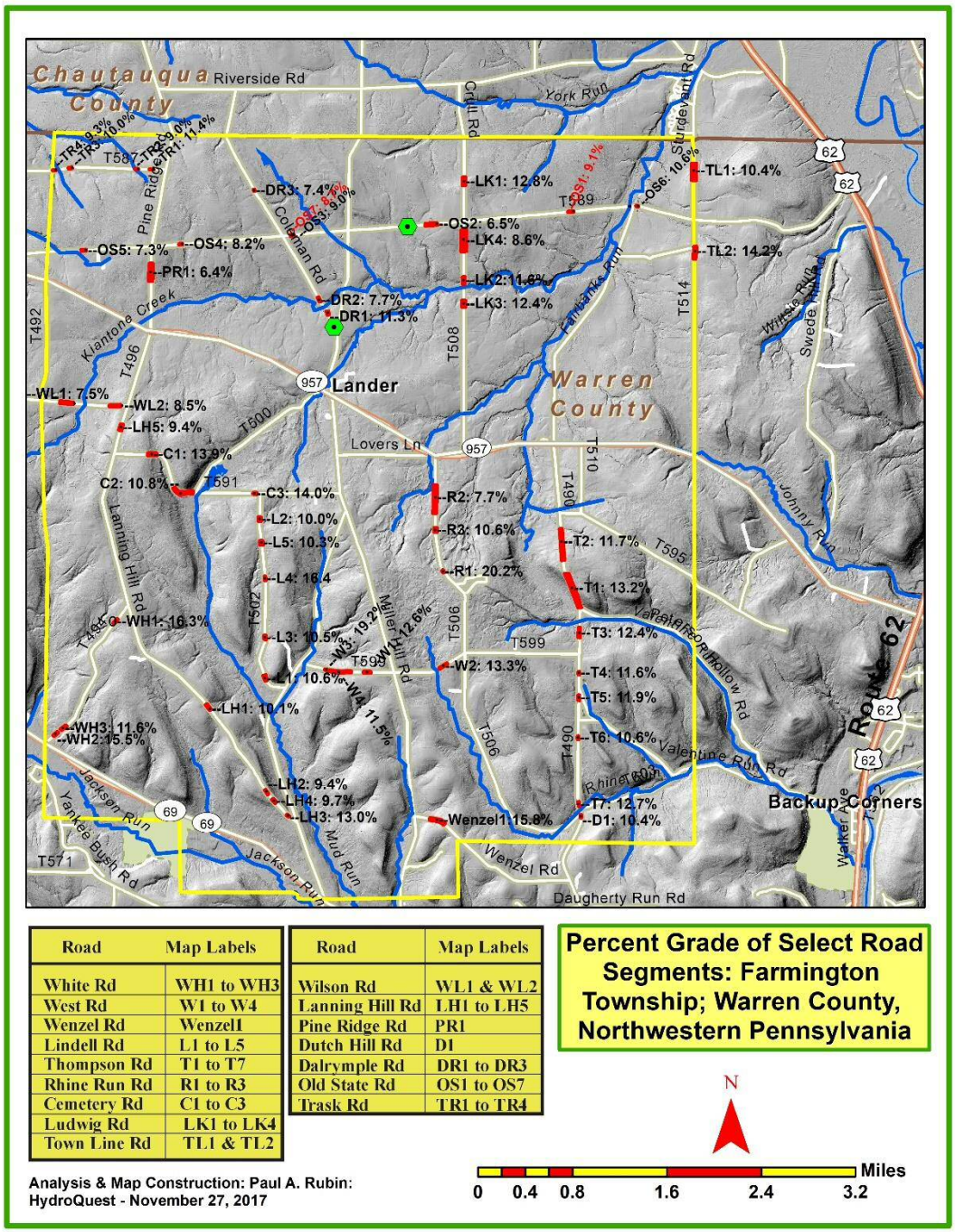
Many steep road sections with grades in excess of 10 percent are situated close to streams (Figure 3) with some steep road segments lying on or very close to drainage divides (e.g., LH2, LH3, LH4). In these settings, chemically laden production brine has the potential of adversely impacting water quality in two watersheds at the same time.



Road	Map Labels
White Rd	WH1 to WH3
West Rd	W1 to W4
Wenzel Rd	Wenzel1
Lindell Rd	L1 to L5
Thompson Rd	T1 to T7
Rhine Run Rd	R1 to R3
Cemetery Rd	C1 to C3
Ludwig Rd	LK1 to LK4
Town Line Rd	TL1 & TL2

Road	Map Labels
Wilson Rd	WL1 & WL2
Lanning Hill Rd	LH1 to LH5
Pine Ridge Rd	PR1
Dutch Hill Rd	D1
Dalrymple Rd	DR1 to DR3
Old State Rd	OS1 to OS7
Trask Rd	TR1 to TR4

Figure 1. Percent grade of topography in Warren County, PA.



Road	Map Labels
White Rd	WH1 to WH3
West Rd	W1 to W4
Wenzel Rd	Wenzel1
Lindell Rd	L1 to L5
Thompson Rd	T1 to T7
Rhine Run Rd	R1 to R3
Cemetery Rd	C1 to C3
Ludwig Rd	LK1 to LK4
Town Line Rd	TL1 & TL2

Road	Map Labels
Wilson Rd	WL1 & WL2
Lanning Hill Rd	LH1 to LH5
Pine Ridge Rd	PR1
Dutch Hill Rd	D1
Dalrymple Rd	DR1 to DR3
Old State Rd	OS1 to OS7
Trask Rd	TR1 to TR4

Percent Grade of Select Road Segments: Farmington Township; Warren County, Northwestern Pennsylvania

N

0 0.4 0.8 1.6 2.4 3.2 Miles

Analysis & Map Construction: Paul A. Rubin: HydroQuest - November 27, 2017

Figure 2. Percent grade of select road segments in Warren County, PA.

Table 1. Values and measurements made to determine percent grade of select road sections. Elevation, difference and distance values are in feet.

Map Label	Location	Elev. 1	Elev. 2	Diff.	Distance	Slope	% Grade
WH1	White1	1740	1782	42	258	0.163	16.3
WH2	White2	1506	1542	36	232	0.155	15.5
WH3	White3	1566	1600	34	292	0.116	11.6
W1	West1	1808	1848	40	317	0.126	12.6
W2	West2	1774	1828	54	405	0.133	13.3
W3	West3	1638	1668	30	156	0.192	19.2
W4	West4	1672	1788	116	1012	0.115	11.5
Wenzel1	Wenzel1	1666	1778	112	707	0.158	15.8
L1	Lindell1	1570	1596	26	246	0.106	10.6
L2	Lindell2	1816	1834	18	180	0.100	10.0
L3	Lindell3	1640	1658	18	172	0.105	10.5
L4	Lindell4	1756	1786	30	183	0.164	16.4
L5	Lindell5	1836	1854	18	174	0.103	10.3
T1	Thompson1	1614	1830	216	1634	0.132	13.2
T2	Thompson2	1642	1806	164	1397	0.117	11.7
R1	RhineRun1	1868	1892	24	119	0.202	20.2
R2	RhineRun2	1634	1732	98	1268	0.077	7.7
R3	RhineRun3	1756	1776	20	189	0.106	10.6
C1	Cemetery1	1860	1916	56	402	0.139	13.9
C2	Cemetery2	1652	1756	104	960	0.108	10.8
C3	Cemetery3	1732	1756	24	171	0.140	14.0
LK1	Ludwig1	1570	1618	48	374	0.128	12.8
LK2	Ludwig2	1432	1470	38	329	0.116	11.6
LK3	Ludwig3	1454	1490	36	291	0.124	12.4
LK4	Ludwig4	1518	1600	82	953	0.086	8.6
TL1	TownLine1	1400	1478	78	748	0.104	10.4
TL2	TownLine2	1486	1566	80	562	0.142	14.2

Table 2. Values and measurements made to determine percent grade of select road sections. Elevation, difference and distance values are in feet.

Map Label	Location	Elev. 1	Elev. 2	Diff.	Distance	Slope	% Grade
WL1	Wilson1	1662	1706	44	588	0.075	7.5
WL2	Wilson2	1696	1740	44	519	0.085	8.5
LH1	LanningHill1	1754	1784	30	297	0.101	10.1
LH2	LanningHill2	1694	1716	22	233	0.094	9.4
LH3	LanningHill3	1578	1596	18	138	0.130	13.0
LH4	LanningHill4	1650	1670	20	206	0.097	9.7
LH5	LanningHill5	1800	1826	26	277	0.094	9.4
PR1	PineRidge1	1610	1660	50	786	0.064	6.4
D1	DutchHill1	1526	1540	14	135	0.104	10.4
T7	ThompsonHill7	1512	1536	24	189	0.127	12.7
T6	ThompsonHill6	1658	1674	16	151	0.106	10.6
T5	ThompsonHill5	1730	1758	28	235	0.119	11.9
T4	ThompsonHill4	1740	1756	16	138	0.116	11.6
T3	ThompsonHill3	1640	1696	56	453	0.124	12.4
TR1	Trask1	1654	1674	20	175	0.114	11.4
TR2	Trask2	1610	1624	14	156	0.090	9.0
TR3	Trask3	1506	1522	15	160	0.100	10.0
TR4	Trask4	1502	1516	14	151	0.093	9.3
DR1	Dalrymple1	1502	1520	18	160	0.113	11.3
DR2	Dalrymple2	1504	1520	16	207	0.077	7.7
DR3	Dalrymple3	1668	1674	6	81	0.074	7.4
OS1	OldState1	1450	1472	22	243	0.091	9.1
OS2	OldState2	1550	1584	34	522	0.065	6.5
OS3	OldState3	1586	1600	14	156	0.090	9.0
OS4	OldState4	1634	1646	12	146	0.082	8.2
OS5	OldState5	1576	1592	16	220	0.073	7.3
OS6	OldState6	1334	1344	10	94	0.106	10.6
OS7	Old State7	1592	1600	8	92	0.087	8.7

Hydrology

When characterizing potential adverse water quality impacts to streams, rivers, ponds, lakes, and wetlands functioning as receptors of chemically-laden wastewater applied on roadways and fields, it is important to first fully map the surface drainage pattern. This is especially critical when considering PA DEP brine spreading approvals that state that *"[B]rine must not be applied within 150 feet of a stream, creek, lake or other water body.*" Hydrologically, it would be prudent to add "drainage ditches" to this listing because it is common practice to maintain drainage ditches

parallel to roadways to rapidly shunt road surface drainage away from roads to streams. Rapid overland transport of brine chemicals directed to surface streams and waterbodies may quickly degrade water quality (e.g., within hours), especially during and following precipitation events.

The DEP Operating Requirement that states *"[B]rine must not be spread on wet roads, during rain, or when rain is imminent.*" fails to consider the accumulation and buildup of contaminants along roadsides and in ditches that may be readily mobilized once significant rain and runoff occur. This hydrologic situation is analogous to the buildup of hydrocarbons on gas station lots or other parking lots (from vehicle leakage) that may remain perched in place until a heavy rain occurs, followed by a chemically-laden first flush of contaminants in a down-gradient direction. In the case of oil and gas well production brine, the list of chemicals posed for off road transport potentially includes sodium, chloride, heavy metals, volatile organics and other contaminants - far more than the two main components of road salt (sodium and chloride). For example, brine samples collected at road locations A & B (Figures 3 and 4) had numerous hydrocarbon contaminants, including benzene (a known carcinogen), and high levels of sodium, chloride, total dissolved solids and high metals concentrations. Table 1 and the text within the attached report provide additional chemical information regarding contaminants posed to runoff into adjacent waterways.

Thus, potential dispersal of brine contaminants into waterways of the Commonwealth should be predicated on full knowledge of the areal extent of the drainageways proximal to roads targeted for chemical disposal via brine spreading. Without a comprehensive map of Township waterways, it is likely that the 150-foot PA DEP Operating Requirement will be and has been breached. To this end, it is important to recognize that existing U.S. Geological Survey topographic quadrangle maps, commonly with 20-foot contour intervals, do not portray the full drainage network present within Townships. Brine haulers operating without comprehensive drainage network maps might inadvertently dispose of gas and oil industry waste fluids on roadways within 150-feet of streams - an apparently arbitrary distance value without empirical supporting justification.

To assess potential contravention of the 150-foot Operating Requirement, a comprehensive photogrammetric analysis of the surface drainage network throughout Farmington Township was conducted (Figure 3). This analysis involved detailed examination of high resolution (1 meter) 1993-1995 black and white Digital Orthophoto Quarter Quadrangle (DOQ) imagery cast on Universal Transverse Mercator Projection (UTM) on the North American Datum (NAD) of 1983. DOQ images analyzed were acquired as part of the USGS National Aerial Photography Program

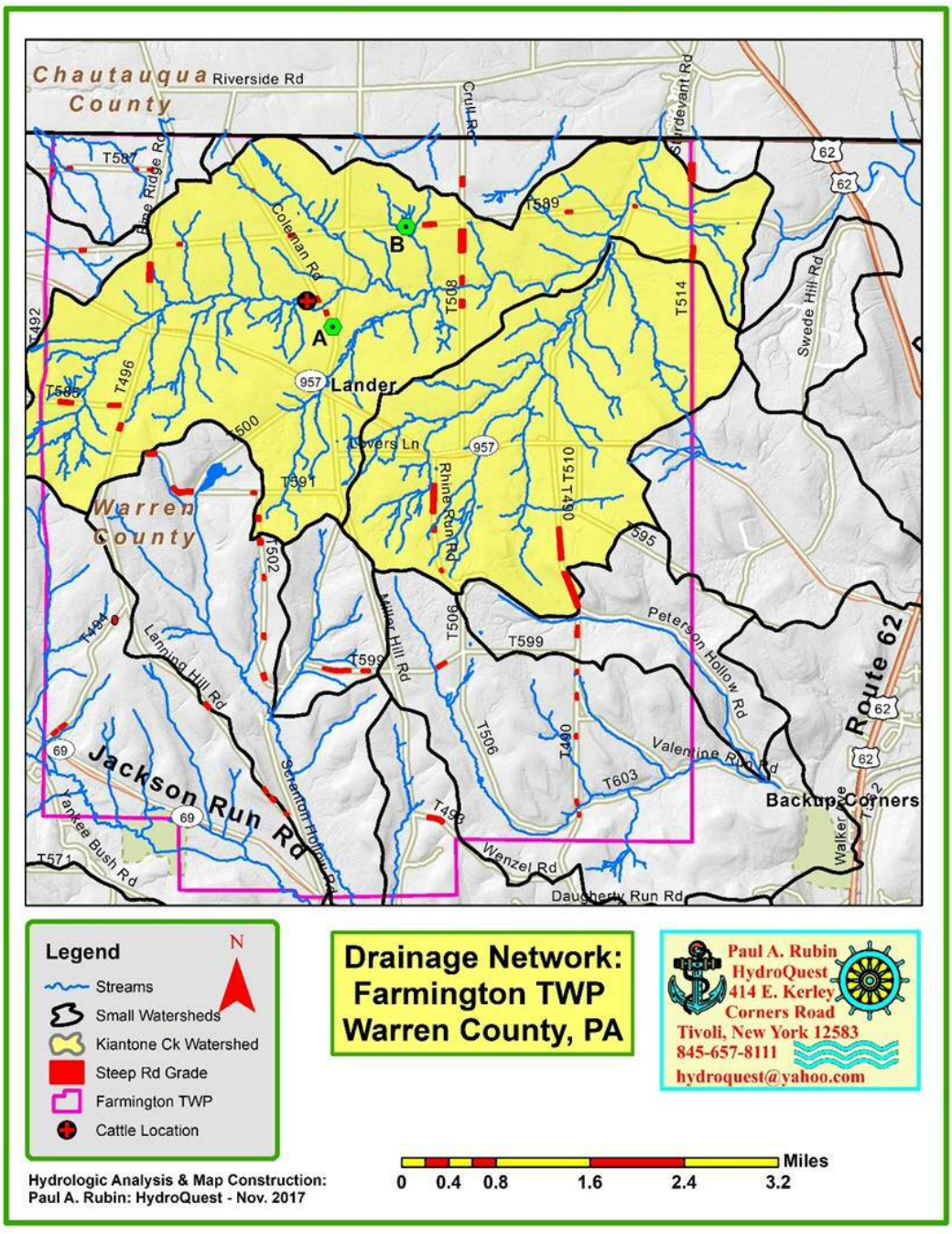


Figure 3. Detailed drainage network in Farmington Township, PA. The Kiantone Creek watershed is highlighted in yellow.

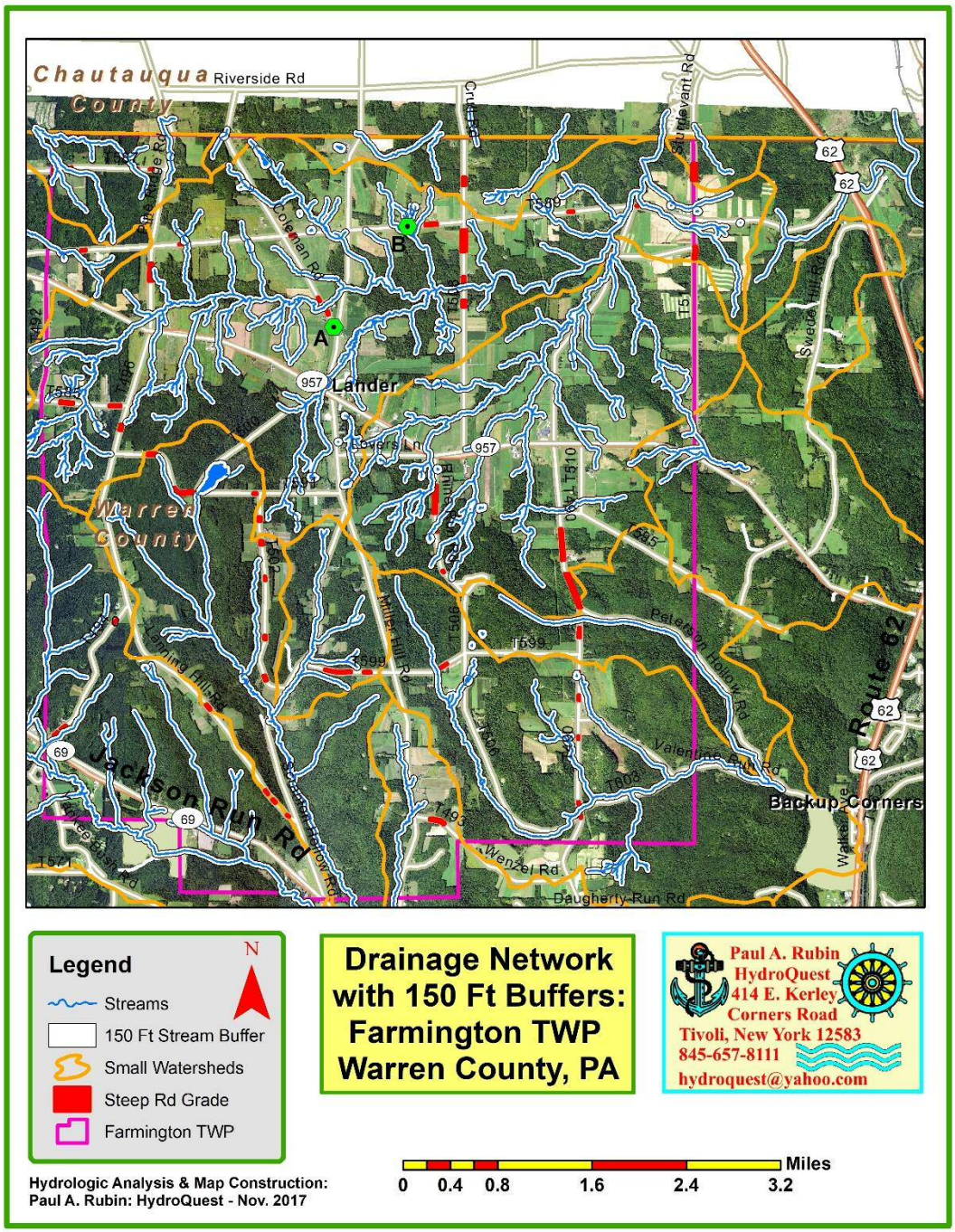


Figure 4. Drainage network with 150-foot buffers outward from streams and ponds.

(NAPP) and were distributed by PA Spatial Data Access (PASDA). The radiometric image brightness values of the images are stored as 256 gray levels which facilitate stream delineation based on tonal differences. Analysis was conducted within the framework of a GIS data base where imagery could readily be examined in a closeup setting. In this manner, stream reaches were digitized. Where tree cover obscured stream segments, reach positioning was reasonably approximated based on USGS topographic contour maps cast in georeferenced Digital Raster Graphic (DRG) format. A comprehensive drainage network map was constructed through this photogrammetric analysis (Figure 3). A 150-foot buffer distance was then applied outward from the drainage network (Figure 4). Figure 4 depicts areas where brined roads are within 150-feet of streams as well as areas where brined road areas are very close to or surrounded by stream reaches. Considering the expansive nature of the well-integrated drainage network present within Farmington Township, the logic behind using Township roads for disposal of oil and gas industry production waste is difficult to comprehend. Brine waste that does not flow directly into streams following major rain or runoff events has a high probability of infiltrating into underlying aquifer water.

Reference to Figure 3 reveals that the stream pattern within Farmington Township is dendritic, resembling that of a spreading oak or chestnut tree. Such patterns form in unconsolidated horizontal sediments in areas having a gentle regional slope at present or at the time of drainage inception. Figure 5 provides an example of unconsolidated sediments along Kiantone Creek.

Figure 5. Kiantone Creek west of Dalrymple Road. Low flow conditions present on October 8, 2017. Cattle and horses drink from this creek. The photo on the left illustrates a normal sequence of floodplain stratigraphy. Note the basal gravel and cobble fluvial deposit indicative of turbulent high flow conditions overlain by fine-grained sediments deposited during overbank flow conditions. Surface runoff from brined roads infiltrates downward into unconsolidated deposits where it may contaminate groundwater resources.

Small headwater watersheds are more vulnerable to contaminant loading than rivers because relatively low stream discharges have lower chemical assimilation potential. Closer examination of the drainage network in and adjacent to Farmington Township documents the headwater setting of the network which drains into Conewango Creek prior to its confluence with the Allegheny River. An excellent example of a headwater setting present in this drainage network is the Kiantone Creek watershed which is highlighted in yellow on Figure 3. Drainage from this watershed occurs as the Kiantone Creek flows northward, crosses into Chautauqua County of New York State, flows to the confluence of Conewango Creek, then turns southeast and flows back into PA, and then flows south to Warren, PA where it joins the Allegheny River. What stands out is that Farmington Township watersheds do not have major rivers flowing into and out of them that might serve to dilute oil and gas industry waste fluids flowing into them. Their headwater settings make surface and groundwater particularly vulnerable to contaminant inputs.

Horses and cattle that ingest water from headwater reaches of Kiantone Creek present an example of livestock that may potentially be adversely impacted by brine waste disposal via spreading on permeable road surfaces (Figure 6). Similarly, people who ingest stream, spring, and well water in the Township also have the potential of ingesting oil and gas industry waste products.

Figure 6. Cows along a low gradient headwater section of Kiantone Creek west of Dalrymple Road (aka Coleman Rd. on some maps). Their location is plotted as a black circle with a red cross within it on Figure 3. Chemically-laden fracking brine may potentially reach these cattle from applications on Wilson, Lanning Hill, Pine Ridge, Old State, and the western section of Cemetery roads. Water quality monitoring during and immediately following runoff events is not conducted.

Sediments removed from drainage ditches along brined roads also pose a risk to surface and groundwater quality when left untreated and placed elsewhere within watersheds (Figure 7).

Figure 7. Drainage ditch sediments pose potential sources of brine related contaminants including metals, volatile organics, and chloride. The practice of spreading contaminated sediments onto fields can result in groundwater and surface water contamination. Land spreading chemically laced sediments is not prudent.

Conclusions

This report documents that many road sections where fracking brine is applied within Farmington Township exceed a ten percent grade, with at least one measured road segment with a grade of 20.2 percent. A number of brined road sections are within 150-feet of streams. Other brined road sections are very close to or surrounded by stream reaches. Small headwater watersheds of Farmington Township are vulnerable to contaminant loading because relatively low stream discharges have low chemical assimilation potential. PA DEPs Operating Requirements for disposal of oil and gas well production brine is not a "*beneficial use*" because it is likely to result in surface and groundwater contamination anywhere it is applied. The flawed hydrologic basis behind PA DEP's Operating Requirements and environmental consequences of brine spreading are further addressed in the attached report titled: Disposal of Oil & Gas Field Produced Waters: A Hydrologic Case Study of PA Brine Spreading Practice.

The disposal of oil and gas industry waste products into the natural resources of Farmington Township and the Commonwealth may be considered to be a violation of Pennsylvania's Environmental Rights Amendment to its Constitution's Declaration of Rights (Article 1, Section 27) that states:

> "*The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.*"

HydroQuest

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November 15, 2011

Scott E. Walters, Chief
General Permits/Beneficial Use Section
Division of Municipal and Residual Waste
Bureau of Waste Management
PO Box 8472
Harrisburg, PA 17105-8472

Delivered via e-mail and overnight USPS

RE: Natural Gas Brine Dispersal on Roadways and the Risk of Surface and Groundwater Contamination (Comments on DEP Permit # WMGR064)

Dear Mr. Walters,

Introduction

On behalf of Damascus Citizens for Sustainability (PO Box 147, Milanville, PA 18443), I have reviewed the Special Conditions General Permit WMGR064 amendment that proposes the authorization of the use of natural gas well brine for roadway pre-wetting, anti-icing, and roadway de-icing. Our comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

I offer comments based on my training as a geologist, hydrogeologist, and hydrologist with 30 years of professional environmental experience which includes work conducted for the New York State Attorney General's Office (Environmental Protection Bureau), Oak Ridge National Laboratory (Environmental Sciences Division), the New York City Department of Environmental Protection, and as an independent environmental consultant as President of HydroQuest. I have conducted detailed assessments of streams, wetlands, watersheds, and aquifers for professional characterizations, for clients, and as part of my own personal research. I have authored numerous reports and affidavits related to this work and have made presentations to judges and juries. In addition, I have published papers and led all day field trips relating to this work at professional conferences. I have also authored extensive comments relating to exploratory wells in the Delaware River Basin, as well other material related to gas drilling and hydraulic fracturing.

This general permit will fail to protect the public and the environment. General Permit WMGR064 paragraph 12 acknowledges the "… *potential for groundwater contamination* …" This permit does not adequately address the short and long-term hydrologic picture and, as such, willingly seeks to conduct "… *an activity that harms or presents a threat of harm to the health, safety, or welfare of the people or the environment*." (Paragraph 14). Similarly, paragraph 6 states that: "*The activities authorized by this permit shall not harm or present a threat of harm to the health, safety, or welfare of the people or environment of this Commonwealth.*" The serious contaminant risk associated with the proposed "beneficial" use of natural gas well brines is accented in paragraph 21 of the Special Conditions:

> *"The permittee/registrant shall immediately notify the Department's Emergency Hotline at (717) 787-4343 and the appropriate DEP regional office in the event of any spill of natural gas well brines in a quantity* ***capable of reaching surface water*** (emphasis added) *and shall take immediate action to protect the health and safety of the public and the environment."*

As a hydrogeologist with 30 years of professional experience I am well aware that road salt which has a high sodium chloride content, like brines, has a long history of contaminating groundwater supplies – often with related litigation. For example, as a hydrogeologist with the New York State Attorney General's Office (Environmental Protection Bureau), I worked with the NYSDEC and NYS Thruway Authority to document the migration of road salt from the road edge to a number adversely impacted homeowner wells. Here, the NYS Thruway Authority ultimately paid to extend a water line to provide potable water to homeowners. This situation spurred extensive research which documented the magnitude of road salt based groundwater contamination cases throughout the United States. This work, in turn, led to drafting legislation oriented toward protecting aquifers from road salt contamination. The proposed application of brines under General Permit WMGR064 would present a similar hydrogeologic risk to groundwater and surface water resources – with the added risk of widespread dispersal of additional and, quite likely, unknown fracking-related chemical compounds. The dispersal of gas well brines on our roadways, potentially laced with toxic and carcinogenic chemical compounds, is completely unnecessary and will needlessly jeopardize our finite freshwater resources. General Permit WMGR064, and any other related permits (e.g., for dust suppression) should be abandoned in deference to traditional means of de-icing our roadways. This permit should be denied.

In part, these comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

Production-Related Brines

It is likely that gas well brine wastewater produced along with gas or oil production will be

targeted for de-icing, dust suppression, and related uses. In this case, it is likely that an even greater percentage or concentration of fracking-related chemicals will be present vs. further along in the final production life of wells. Concentrated and chemically-laden brines should not be discharged into the environment. This is not a beneficial use. These brines need to be properly treated and disposed of.

Gas Well Closure

Former natural gas wells should be immediately plugged and abandoned following cessation of production. They should not be adapted for yet another use (i.e., brine extraction) that will, without doubt, degrade the water quality in the Commonwealth. General Permit WMGR064 seeks to provide a beneficial use of natural gas well brines for roadway and walkway purposes. Although unclear in the permit description, one underlying premise here may be that gas wells should remain open for a period of time after productivity diminishes. This would require that wells not be fully plugged and abandoned following cessation of gas production. To delay permanent closure of any natural gas well actively accepts and knowingly extends the great environmental and water quality risks attendant to gas production in the Commonwealth and elsewhere. On behalf of Damascus Citizens for Sustainability, the Delaware Riverkeeper Network, and independently on behalf of HydroQuest, HydroQuest has documented the environmental risks to freshwater aquifers stemming from gas wells.

All gas wells should be immediately plugged and abandoned once production is stopped because the durability and mechanical properties of well sealant materials are NOT sufficiently advanced such that freshwater aquifers will be safely protected for hundreds of thousands of years. Existing and so-called "state-of-the-art" plugging and abandonment (P&A) practices and materials are not sufficiently advanced to insure long-term isolation between saline and freshwater zones. The aquifers we enjoy today took about a million years to form and can reasonably be expected to last another one million years (see, for example, attached *Aquifer Protection Expert Fact Sheet*). [This Fact Sheet may also be viewed and downloaded at: http://hydroquest.com/Hydrofracking/] Without unnatural alteration from gas drilling activities, aquifers should be capable of providing potable water for future generations for another one million plus years. Industry documentation establishes that, under the best of circumstances, cement and steel used to effect zonal isolation may last up to 100 years and 80 years, respectively – often far less. Once the inevitable failure of cement sheath and casing sealant material occurs, additional contaminant migration pathways are available. Then, methane released under pressure from failed cement sheaths and casings follows fractures to homeowner wells, water bodies, and the land surface. With continued degradation of cement sheaths, concentrated brine fluid will rise under hydraulic pressure and commingle with freshwater aquifers. Thus, under this scenario, the intended "beneficial use" of natural gas well brines requires that freshwater resources remain at risk for extended periods of time.

As stated in Chapter 7 of Pennsylvania's Well Abandonment Procedures (Section 7.1 Introduction):

> *"Unsealed or improperly sealed wells **may threaten public health and safety, and the quality of the groundwater resources*** (emphasis added***)***. *Therefore, the proper abandonment (decommissioning) of a well is a critical final step in its service life. ... Proper well abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers."*

Clearly, any action regarding non-producing gas wells, other than immediate plugging and abandonment, should be banned and construed as not following the intent of existing well field regulations. Extended gas well life threatens freshwater resources in the Commonwealth, with the result being the dispersal of contaminants that hydrologically must and will enter surface and groundwater resources if spread in this manner – anything but a "beneficial use". This permit must be denied.

Gas Well Brines

De-icing chemicals commonly enter nearby groundwater flow systems and degrade water quality. State and Federal drinking water standards for groundwater, against which adversely impacted homeowner well waters will be compared for gas well brine chemicals, are limited and do **NOT** adequately require sampling and analysis for all of the many toxic and carcinogenic chemical compounds used in fracking/drilling fluids. As a result, State sign-off on supposedly clean, potable, groundwater will occur while people's health may remain in serious jeopardy from unknown and untested brine chemicals. Therefore, this permit must be denied.

Natural gas well brines are comprised of concentrated solutions of sodium chloride, laced with numerous known and unknown hydrofracking chemicals, many of which may be toxic. The Pennsylvania Department of Environmental Protection developed a Fact Sheet that pointedly explains to the public the definition and the potential "beneficial use" of brine in the Commonwealth:

> *"Brine is the general term used for wastewater produced along with oil or gas; it can be very salty, therefore, **injurious to plants and aquatic life*** (emphasis added)."

It is not prudent from a hydrologic and water quality standpoint to intentionally disperse **wastewater** throughout the Commonwealth so that it will flow and infiltrate into our surface water and groundwater resources. Whether brine contaminants are applied on dry days, wet days, 50 or 200 feet from streams or houses, or in one concentration or another is largely irrelevant. The hydrology is simple and straight forward. Under wet hydrologic conditions, and with repeated applications, whether today, tomorrow, or in two months – the contaminants **will move** into our waterways, reservoirs, and aquifers (i.e., toward our drinking water supplies). Once significant precipitation occurs, brines will then be mobilized and transported away from source areas. To categorize gas well brine applications under the term "beneficial use" can only be considered from a financial perspective relative to saving gas companies from having to pay

to properly dispose or treat their wastewater. The concept of intentionally dispersing gas well wastewater into our environment defies all common sense. Thus, this permit application should be denied.

General Permit WMGR064, Table 1, provides acceptance criteria (i.e., allowable concentrations) for fourteen chemical parameters, some of which are not typically contaminants when present in normal background concentrations in groundwater. The comparative table provided below readily indicates that this general permit will knowingly allow chemical laden brines to enter contaminant-free surface and groundwater flow systems.

Parameter	Allowable Level Pre-wetting (mg/l except pH)	Primary or Secondary Drinking Water Standard (mg/l except pH)	Minimum number of times in excess of Groundwater Standard
TDS	>170,000	500	>340
Chloride	>80,000	250	>320
Sodium	>40,000	-----	------
Calcium	>20,000	-----	------
pH	5 to 9.5	6.5-8.5	10-50
Iron	<500	0.3	<1,667
Barium	100	2	50
Lead	10	0.005	2,000
Sulfate	<1,000	250	<4
Oil & Grease	< 15	-----	------
Benzene	<0.5	0.005	<1,000
Ethylbenzene	<0.7	0.7	<1
Toluene	<1	1	<1
Xylene	<1	10 (total)	------

Even if we erroneously assume that the only chemicals present in brine-rich waters pumped from gas wells are all included in the above parameter list, many of those present will assuredly contaminate surface and groundwater resources adjacent to and beyond roadways. Chloride, for example, is extremely soluble in water and is readily transported in both surface and groundwater flow systems. It is well-recognized as a contaminant that has degraded numerous homeowner wells. Studies have shown that it often moves coincident with large snowmelt, precipitation, and runoff events. Repeated applications provide regular replenishment of contaminant source material. The addition of fracking-related chemicals to traditional de-icing materials will serve to greatly increase the health risk to the general populous and the environment. To limit permit *acceptance criteria* largely to chemical parameters that have established MCL's would ignore hundreds of other chemicals that are used in underground fracking injection, plus many others that are hidden from public scrutiny by being labeled as "proprietary". This would oppose the best interests of the population at large. A comprehensive listing of hydrofracking related chemicals is provided in the text and many tables of Chapter 5 of

the NYS Revised DSGEIS. The material in this chapter (http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf) is hereby incorporated by reference. Permit acceptance criteria must be greatly expanded to include all toxic and carcinogenic chemicals that may well be within the brine "chemical soup" as indicated within Chapter 5 of the NYS DSGEIS. Allowable levels of these many chemical parameters must be based on detailed toxologic testing and risk assessment evaluations. In addition, individual testing of gas well brines should be conducted at least annually on a well-specific basis.

Many more contaminants that are present in flow back water are also likely to be present in brines pumped from gas production wells. Some of these are extremely toxic, some are carcinogens, and others have not been adequately studied to determine their potential impact on humans and animals (e.g., 2-butoxyethanol, formaldehyde). For example, Dr. Ronald Bishop details many of the toxic qualities and potential health impacts associated with chemicals wastes found in gas well flow back water (http://www.fmce.org/Beyond%20MSDS.pdf; *Beyond MSDS: A Review of Hazardous Materials Used by New York's Natural Gas Industry*). Dr. Bishop's report is hereby incorporated into this comment letter by reference. As discussed above, these and all other hydraulic fracturing and drilling fluid chemicals should be comprehensively assessed by toxicologists and should then be added to the very short and incomplete list above. There are hundreds of chemicals used in the hydraulic fracturing and well drilling process, many not disclosed to the public. To not identify and test for **all** these chemicals and to then exclude them from the "*acceptance criteria*" is short-sighted and irresponsible, especially in light of the many documented and serious public health risks.

Hydrology Discussion

Under 25 Pa. Code § 287.611(a)(3), the Department of Environmental Protection—here through the Bureau of Waste Management—can issue a general permit for beneficial use of residual waste if it can be used "without harming or presenting a threat of harm to the health, safety or welfare of the people or environment" of the Commonwealth. **Hydrologically, this cannot be done.** Slow groundwater flow rates and rapid surface runoff will recharge aquifers and streams with brines and related contaminants. Thus, contaminant plumes will move toward homeowner wells and streams. These plumes, like those present at other contaminant sites, need to be treated as outwardly expanding contaminant plumes that warrant expensive, full-scale, hydrogeologic characterization, groundwater clean-up, and remedial action. Hydrogeologically, overland brine dispersal is short-sighted and virtually guarantees degradation of both surface and groundwater resources. The draft permit regulations need to be modified to reflect characterization and clean-up of brine-rich waters and all related toxic chemicals present and moving within the environment.

Brine application is not needed for dust suppression. Dust suppression can be achieved with the application of clean water and need NOT contain ANY brines or chemical additions that pose an unnecessary threat to clean surface and groundwaters of the Commonwealth. As such, General Permit WGMR064 should be abandoned.

Tracers

Tracer additions to brines would provide a much needed checks and balance type approach to scientifically and legally address claims of brine excursions. On the one hand, tracers would readily allow brine applicators to show they are not behind brine-related contaminant issues that are not of their making, while on the other hand it would remove the oneness of proof from homeowners actually adversely impacted. **Importantly, there is no reason whatsoever that ALL brine applications should not require tracer additions and monitoring effective immediately, even before general Permit WMGR064 is approved. This would demonstrate a good faith effort on behalf of the regulators.**

To reduce the onus of legal and expert consultant costs to homeowners, **all** brine waters/fluids should first have company-specific tracers added to them so contaminant source and responsibility can be properly assigned (should this permit be approved). The addition of gas well company-specific tracers is needed to provide sufficient documentation of uncontrolled non-point source de-icing chemical excursions from roadways and walkways. Otherwise, the limited number of Maximum Contaminant Level (MCL) chemicals may erroneously instill a false sense of potable water quality when people's health may be severely impacted. The enforcement of these provisions is nearly impossible. The department cannot consider approval of this permit application without a highly detailed enforcement plan to be implemented with the completed permit application. An enforcement plan should be part of the permit. Without this, the permit should be rejected.

Proposed Modifications in the Event the Permit Application is Approved

Substantively, the proposed modifications present a risk of damage to human health and the environment and should therefore be rejected. Hydrologically, dispersed/applied brines will enter and degrade the environment in a very non-beneficial manner. Application rates, timing, and set-back distances will do little other than postpone the inevitable. Besides, there is no provision for enforcement in this permit application. Therefore, we recommend rejection of this permit. If, however, the Bureau decides to go ahead with the new uses, it should include the following criteria in the General Permit in order to substantively comply with its mandate to somewhat protect human health and the environment:

- THIS IS THE MOST IMPORTANT NEW CRITERIA. Add company-specific chemical tracers to all gas well fluids prior to brine application so that contaminant responsibility, aquifer restoration and alternate water supply costs may be properly designated. Tracer experts should be used to determine appropriate tracers and concentrations so as to fully allow for detection in degraded surface and groundwater resources of the Commonwealth.

- **NO PERMIT APPROVAL SHOULD BE POSSIBLE WITHOUT THIS CRITICALLY IMPORTANT CRITERIA DESIGNED TO PROTECT BOTH ADVERSELY IMPACTED HOMEOWNERS AND BRINE APPLICATORS. UNWILLINGNESS TO USE TRACERS TO DOCUMENT CONTAMINANT RESPONSIBILITY SHOULD BE CAUSE ALONE TO NOT APPROVE GENERAL PERMIT WMGR064**;

- Develop appropriate acceptance criteria for the new uses that includes all chemicals used in gas well drilling and fracking;

- Conduct comprehensive chemical and toxicological testing of fluids from all gas wells targeted for brine extraction for ALL chemicals previously used in them during construction and development. Sample collection and analysis should be conducted by an independent party;

- Conduct baseline chemical testing of all well water and surface waterways, lakes, and reservoirs for ALL chemicals previously used in the gas wells to a distance of 2,000 feet outward from all roadways and walkways;

- Provide for regular testing of brines including gas well chemicals used every six months or sooner where degraded groundwater and/or surface water is suspected;

- Provide for regular testing of soil and groundwater within 2,000 feet of application for ALL chemicals used in gas well fluids during construction and operation of gas wells;

- Provide criteria to stop all brine spreading should **any** surface or groundwater contamination be documented;

- Establish a 2,000 foot limit on brine application distance from water bodies and streams;

- Special Protection Waters, Caves & Mines. Recognize, locate, investigate, inventory, and characterize rare, threatened, and endangered species and their habitats which are likely to be degraded from brine-related contaminant excursions. Omit these habitat areas from brine applications, inclusive of a large buffer distance. Some of the species of greatest concern are endangered stream dwellers (i.e., Dwarf Wedge mussel [*Alasmidonta heterodon])* and assorted bat species (e.g., including the federally endangered Indiana bat [*Myotis sodalis]*). There are real environmental, water quality, health, and endangered species concerns regarding brine excursions into carbonate beds, inclusive of in caves and mines. Carbonate formations in portions of the Commonwealth are recognized among karst hydrologists as being karstic or cave/ conduit bearing in nature. Brine and related contaminants that may enter karstic

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solution conduits, from below or above, would quickly degrade groundwater and surface water quality;

- Add a monitoring section. The General Permit lacks detail on surface and groundwater monitoring. This should be added. Until such time as it can be demonstrated that adequate staffing is present to monitor this general permit, it should not be approved;

- Add an enforcement section. The General Permit lacks provision for enforcement. This should be added. Until such time as it can be demonstrated that adequate staffing is present to regulate and enforce this general permit, it should not be approved;

- Add record keeping detail by PA DEP. Detailed records of the quantity of brine fluids withdrawn and applied should be required;

- Add record keeping detail BY PA DEP. Detailed records of the exact location of brine applications should be required;

- Establish a very substantial escrow or bond type account for all brine applicators to off-set contaminant testing, aquifer restoration, and replacement water supplies costs for adversely impacted parties. This might be set-up on a fee per application basis;

- Establish a rigorous fee structure based on volume of brine application for applicators such that monies are regularly added to the coffers of the Commonwealth. Otherwise, there is no logical reason or beneficial use that may reasonably be attributed to intentionally applying brine wastewater that will threaten and degrade fresh surface and groundwaters of the Commonwealth; and

- Strengthen permit regulations to insure that brine applicators, and/or their suppliers, assume full legal and financial responsibility for contaminating aquifers and fully clean them up to the maximum extent possible **AND** develop permanent alternate water supply systems for all adversely affected water supplies. Permit regulations should be modified to provide for system operation and maintenance costs in perpetuity. As written, permit regulations do not have adequate provision to protect the health and safety of homeowners. The importance of this must be underscored because aquifer restoration from brine and gas field contaminants, even if cost were not an issue, may not be possible. Whereas monetary compensation to adversely affected homeowners may be warranted as settlement for inconvenience, property devaluation, and health issues, any settlements should in no way remove the

responsibility of brine applicators to restore the waters of the Commonwealth. Provision of whole house water filtration systems should not be an acceptable means of abdicating responsibility and liability.

Conclusions

The Bureau should reject the permit modifications, ban any and all gas well brine applications, and not allow the additional proposed uses because of the increased risk of contamination of groundwater, surface waters, and soil. The Bureau's proposed modifications, which will likely drastically increase the amount of brine being spread on Pennsylvania roads, present a threat of harm to the health, safety, and welfare of the people and the environment, and therefore the modifications should be denied.

The key to maintaining high quality groundwater and surface water throughout the Commonwealth is to NOT apply concentrated and contaminated brines at any time whatsoever. There is NO sound environmental benefit in applying brines anywhere, as they will eventually reach surface and groundwater resources. Thus, General Permit WGMR064 should be abandoned and gas well brine applications should be banned permanently. The Bureau should therefore deny the proposed modifications and ban gas well brine dispersal into the environment.

Sincerely.

Paul A. Rubin
Hyrogeologist
HydroQuest

CC: Damascus Citizens for Sustainability