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September 12, 2016

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Kimberly Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Re: PennEast Pipeline Project's Impacts on Drinking Water
FERC Docket No. CP15-558

Dear Ms. Bose:

I am writing on behalf of Homeowners Against Land Taking-PennEast ("HALT"). HALT represents over two hundred impacted landowners in towns along PennEast's proposed pipeline route. HALT intervened in this proceeding on February 3, 2016. Its members are concerned that the Draft Environmental Impact Statement (DEIS) does not accurately assess the risk of arsenic contamination from the proposed pipeline in groundwater, including landowners' drinking water.

It is well known that arsenic concentrations in water can lead to short-term and long-term health effects, including increased cancer risks, cardiovascular effects, numbness and burning sensations, nausea, and other health risks. HALT is alarmed that FERC has failed to consider these impacts on public health from the construction and operation of the pipeline, despite clear and uncontroverted evidence that the abundant concentrations of arsenic in the areas of New Jersey along the proposed pipeline likely will be mobilized by both construction and operation of PennEast's pipeline.

Although Section 4.1.5.5 of the DEIS provides superficial discussion of the risk that the pipeline would cause arsenic contamination of local water sources, the DEIS's analysis of this risk is deeply flawed for multiple reasons.

First, the DEIS relies on a defective study of arsenic contamination provided by PennEast (the Serfes Report).¹ FERC must withdraw the DEIS and base its conclusions on an accurate study. Otherwise, FERC's blind reliance on a study whose errors have been demonstrated on the record to FERC violates NEPA.²

¹ DEIS at 4-12.

² *Seattle Audubon Soc'y v. Espy*, 998 F.2d 699, 704 (9th Cir. 1993) (agency needed to consider intervening report that called into question the study upon which agency originally relied); *Van*

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The comments filed by Professor Tullis Onstott—a Princeton University Geosciences professor and leading expert on the mobilization of arsenic and other ions in New Jersey groundwater—on August 2, 2016 systematically outline the many flaws in the Serfes Report.³ These include, but are not limited to:

- Using an inappropriate and unrepresentative grain size for shattered rock in the experiments;
- Conducting only a dry aerobic experiment even though anaerobic conditions will exist along the proposed pipeline pathway;
- Selecting an insufficient time period and temperature for the experiment;
- Failure to use groundwater in the experiments to more closely mirror local soil conditions.

The Serfes Report is defective and cannot serve as the rational or verifiable bases for FERC’s conclusion that the risk of arsenic contamination to water sources is low. The supplemental comments from Professor Onstott also show that the risk of arsenic contamination is much higher than the Serfes Report concluded.⁴ Several other geochemists from prominent universities concurred with Professor Onstott’s criticisms of the Serfes Report and findings about the need to conduct new studies before FERC can evaluate the adverse impacts on water supply wells, endangered species, and arsenic discharges into the Delaware River.⁵ Because of the many inaccuracies in the Serfes Report, FERC must withdraw the DEIS and reevaluate the risks of arsenic contamination using corrected, site-specific information.

Second, despite being informed by Professor Onstott as early as February 26, 2015 that long-term operation of the pipeline posed a larger threat of arsenic contamination than construction, FERC’s DEIS only analyzes the risks from construction.⁶ Failure to analyze known risks from pipeline operation is a fatal gap

(Continued . . .)

Abbema v. Fornell, 807 F.2d 633, 639 (7th Cir. 1986) (holding agency’s action violated NEPA because agency based its conclusions on information that it had reason to believe was defective).

³ FERC Docket No. CP-15-558, Accession No. 20160802-5034 (attached as Exhibit A).

⁴ FERC Docket No. CP-15-558, Accession No. 20160906-5247; FERC Docket No. CP-15-558, Accession No. 20160907-5050 (attached as Exhibit B).

⁵ FERC Docket No. CP-15-558, Accession No. 20160912-5411.

⁶ FERC Docket No. CP-15-558, Accession No. 20160802-5034 (Exhibit A).

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in the DEIS's analysis.⁷ This failure to analyze an adverse impact also means that any mitigation measures developed to address arsenic will not take into account the potential risks from pipeline operation. NEPA requires FERC analyze all significant environmental impacts.⁸ Under this standard, FERC cannot exclude uncontradicted data analysis of the potential impacts from pipeline operation.

Third, many of the risks from construction have not been analyzed. The DEIS contains no analysis of arsenic concentrations in stream channel soils in the project area, which are more than 1,000 times greater than New Jersey Surface Water Quality Standards. Professor Onstott has submitted the only evidence in the record on the mobilization of arsenic in this soil and the environmental risks posed to water quality and the health of thousands of impacted residents from construction activity and the removal of surface vegetation and topsoil near stream crossings.⁹ The DEIS arbitrarily concluded there would be no detectible risks to public health during construction despite these measurements showing that arsenic will be mobilized and concentrations are likely to far exceed state water quality standards. The DEIS does not provide the required "full and *fair* discussion"¹⁰ because it adopts only PennEast's information and disregards without analysis all contrary evidence. Nor has the DEIS considered the mobilization during construction or operation of other chemicals known to be present in the area, such as boron, that could contaminate drinking water and pose additional health risks.¹¹

Fourth, the DEIS is missing data on the location of water sources for nearly 70% of the potentially impacted area in New Jersey. The DEIS cannot comply with NEPA when site-specific information is so severely lacking.¹² FERC cannot conclude that water sources are not at risk of arsenic contamination when FERC has not yet determined the location of a majority of those water sources or evaluated the soil conditions near those water sources.

⁷ *Sierra Forest Legacy v. Sherman*, 646 F.3d 1161, 1180 (9th Cir. 2011) (finding that to take a "hard look" the agency cannot "improperly minimize negative side effects.").

⁸ 40 C.F.R. § 1502.16.

⁹ FERC Docket No. CP-15-558, Accession No. 20160819-5209 (attached as Exhibit C).

¹⁰ *Los Padres ForestWatch v. U.S. Bureau of Land Mgmt.*, No. 15-cv-04378, at 6 (C.D. Cal. Sept. 6, 2016) (emphasis added).

¹¹ FERC Docket No. CP-15-558, Accession No. 20160829-5085 (attached as Exhibit D).

¹² *Pub. Emps. For Env'tl. Responsibility v. Hopper*, No. 14-5303, 2016 WL 3606363, at *2-3 (DC Cir. July 15, 2016) (finding agency failed to take a "hard look" because it did not gather site-specific data that was necessary to determine the effects and consequences of the agency action).



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FERC cannot develop the necessary mitigation and avoidance measures for potential arsenic contamination when its analysis of the risk is fundamentally flawed. This jeopardizes the lives and health of HALT members whose drinking water could be contaminated by arsenic if the pipeline is built. HALT asks FERC to withdraw the DEIS until FERC obtains an accurate study of arsenic contamination risks and gathers site-specific information on drinking water sources along the pipeline route.

Best regards,

s/ R. Steven Richardson

Exhibit A

My name is T.C. Onstott. I am an Intervenor regarding docket CP15-558-000 for the PennEast Pipeline. I am a professor at Princeton University. I am commenting on a report submitted to the FERC by the PennEast Pipeline Company, LLC entitled Attachment 2-1 – Arsenic Study Report.

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Comment on HMM/Solution Geosciences Report on Arsenic

Prof. T.C. Onstott
Dept. of Geoscience
Princeton University
Princeton, NJ 08544

Background to PennEast Arsenic Issue

Medha Kochhar, who is the FERC environmental project manager for the PennEast Pipeline project, was present at the meeting held on February 26, 2015 at The Grand in Hampton New Jersey where Prof. Onstott personally testified about the potential arsenic (As) contamination due to the long-term operation of the proposed PennEast pipeline and of the As halo associated with the Algonquin pipeline (see meeting minutes and recorded testimony). In his testimony he outlines how bacteria would reduce arsenate to arsenite thereby mobilizing its spread into the groundwater. The importance of this As issue in the March 4, 2015 conference call between the FERC, Tetra Tech, PennEast and various agencies (see meeting minutes posted on the FERC website).

In a letter to the FERC from PennEast on June 4, Anthony Cox stated that, “PennEast continues to evaluate argillite, **arsenite** and arsenic concerns associated with **construction**. There is no indication that **construction** will lead to dangerous degradation in drinking water quality. Pre- and post-construction water testing will determine if any degradation occurs. In the extremely unlikely chance that water quality is compromised, PennEast will take measures to provide replacement supplies until the situation is corrected.” He furthermore stated that the details of this will be reported in (Project, 2014) Report 2 of the final filing. This statement was reiterated in a July 9th report submitted to the FERC by Anthony Cox. **NOTE that PennEast has focused just on potential release during construction, not on the As release during operation, which was considered the most serious threat as stated in Prof. Onstott’s official filing with the FERC on February 26, 2015.**

On July 31st, 2015, the FERC staff requested that PennEast “Include a discussion in Draft Resource Report 9 responding to comments expressing concern that pipe trench excavation would cut through As rich Triassic shales of the Passaic and Lockatong formations, and that **methane leaks in subsurface soil would allow As compounds to be converted into water-soluble forms by bacteria.**”

On August 7th, 2015, Anthony Cox replied in a letter to the FERC stating that the information will “Not addressed in RR9. Will be provided in September filing”.

On August 11th, 2015, Anthony Cox in reply to the FERC requested that they respond to the issue of “Arsenite in water, blasting through argillite, anticorrosion electrodes creating galvanic corridor for bacteria to convert to arsenite”, states that “PennEast continues to evaluate

argillite, **arsenite** and arsenic concerns **associated with construction**. The proposed pipeline route goes through parts of Hunterdon and Mercer Counties, where there is naturally-occurring concentrations of As from sulfide minerals that occur in some of the bedrock formations underlying these areas”. **NOTE that PennEast has focused just on potential release during construction, not on the As release during operation, which was considered the most serious threat as stated in Prof. Onstott’s his official filing with the FERC on February 26, 2015.**

On September 14, 2015, Anthony Cox communicated to the FERC that, “Experts have been retained to conduct a risk assessment of the potential leachability of As-bearing rocks within the Lockatong and Passaic formations. The initial results of this analysis will be included in Resource Reports 2 and 6.” **NOTE that no mention is made of arsenite or bacteria.**

On October 8th, 2015, Anthony Cox reported to the FERC that, “A study of the potential for As mobilization from rock resulting from construction activities is underway.” **NOTE that PennEast has focused just on potential release during construction, not on the As release during operation, which was considered the most serious threat as stated in Prof. Onstott’s his official filing with the FERC on February 26, 2015.**

On October 30th, 2015 Ms. Kochhar in a letter to Anthony Cox requested that PennEast provide critical synopsis on environmental information in their report. Anthony Cox replied on November 3rd, 2015, by stating that they will “Provide a copy of the focused As risk assessment, as mentioned on p. 9-12, when available.” This was to be placed in the section on Air Quality.

On November 24th, 2015, Ms. Kochhar requests that PennEast “Utilizing state agency sources (Pennsylvania Department of Conservation and Natural Resources, and NJDEP Geological and Water Survey) provide a discussion of all consultations, and research conducted regarding karst areas of Pennsylvania, and the density of karst features crossed by the proposed pipeline route (i.e. Digital Karst Density Layer and Compilation of Mapped Karst Features in Pennsylvania - (<http://pubs.usgs.gov/of/2003/of03-471/reese/>); and areas underlain by Newark Basin sedimentary bedrock with known elevations of As in groundwater, and suggested monitoring and mitigation measures recommended by these agencies during construction.” **NOTE that the FERC has now also focused just on potential release during construction, not on the As release during operation, which was considered the most serious threat as stated in Prof. Onstott’s his official filing with the FERC on February 26, 2015.**

On February 10, 2016, Ms. Kochhar requests additional information from Anthony Cox in order for “for us to continue preparation of the environmental impact statement (EIS). Once we have received your responses and reviewed them for completeness, we will be able to establish a schedule for completing the EIS.”

NOTE that As was not on the list of information required even though PennEast had not provided any information on As at this time.

On April, 2016 – PennEast finally replies to the following the FERC request “Provide an update and discussion concerning the status and the results for the laboratory As mobilization study program PennEast plans to conduct in association with Dr. Michael E. Serfes; identify and discuss any quantifiable risks from As mobilization in groundwater due to construction and operation of the Project pipeline (if any); and all mitigation measures proposed (if any) to eliminate risks to the public and/or ecological receptors during construction and operation of the Project pipeline from As mobilization.”

Their reply is the following:

“PennEast retained Dr. Michael Serfes, P.G., of Solution Geosciences, LLC to provide his unique expertise to evaluate concerns that commenters expressed to the FERC related to the potential mobilization of naturally occurring As in certain areas of Hunterdon and Mercer Counties, New Jersey. Over the course of 12 weeks, Dr. Serfes completed a comprehensive, independent leachability evaluation. Dr. Serfes conducted leach testing of samples along the proposed excavation transect, using both regional samples of representative rock formations and samples taken directly from geotechnical borings along the pipeline alignment. Dr. Serfes applied the industry-standard test method (USEPA Method 1627: Kinetic Test Method for the Prediction of Mine Drainage Quality) and a modified standard test method (USEPA Test Method 1311 – TCLP, Toxicity Characteristic Leaching Procedure). The purpose of Dr. Serfes’ study was two-fold: first, to evaluate concerns of mobilizing As from trench backfill consisting of enriched As bearing rock fragments generated during pipeline trenching activities; and second, to evaluate concerns of mobilizing As from similar As-enriched rock during HDD activities, where PennEast proposes HDDs under several sensitive resources along the Project alignment. Dr. Serfes completed this independent study, the results of which are provided herein as Attachment 2-1, “Arsenic Study Report.”

The results from Dr. Serfes’ study demonstrated the following:

- (1) that broken fragments of naturally-occurring As-enriched rock, generated during trenching activities and subsequently returned as trench backfill, will not result in significant As mobilization into the hydrogeological environment; and
- (2) that the drilling mud, used for HDD under water courses, will not become significantly contaminated with particles of naturally occurring As enriched rock, that mobile fractions of As will not contaminate the environment, and that the As-enriched rock-mud mixture will not require handling and disposal as a hazardous waste class.

Based on the study results, Dr. Serfes concluded that **construction activities** should not result in any As-related impacts. Accordingly, PennEast does not anticipate any detectable risks from As mobilization in groundwater due to Project construction. The study clearly demonstrates that **background concentrations will return within a short time** after the pipeline is completed. Consequently, PennEast does not anticipate any increase in As concentrations over background

levels during Project **operation**. For these reasons, no mitigation measures related to As mobilization are necessary during Project **construction and operation**.”

Note that PennEast clearly states that Dr. Serfes’s conclusions apply only to construction activities. PennEast then concludes that no mitigation measures are required during construction and operation, completely ignoring Prof. Onstott’s comment on mobilization of As during operation of the pipeline in his official filing with the FERC on February 26, 2015.

On May 11th, 2016, Hatch Mott McDonald submits the final report for the As leaching analyses that is mentioned above. We refer to this report herein as the HMM/Solution Geosciences Report.

In summary, Ms. Kochhar and the FERC requested three times that PennEast Pipeline address the comments made by Prof. Onstott concerning the impact of long term operation of their proposed pipeline on the spread of **arsenite produced by bacteria** into groundwater. PennEast however refused to address this potential environmental hazard, which Prof. Onstott treated as the most serious concern. Instead they focused just upon the spread of As during construction by performing a leaching experiment.

Major Flaws Regarding the Arsenic Leaching Experiments

On page 1 in the Executive Summary, the HMM/Solution Geosciences Report states the following: “In addressing public comments from dockets submitted by citizens, groups and municipalities concerned about the possibility for the significant mobilization of As in relation to the proposed pipeline, PennEast was responsive in addressing them by funding this project. Specifically, the two major concerns are: **Concern (1)**: That broken fragments of naturally-occurring As-enriched rock, generated during trenching activities and subsequently returned as trench backfill, might result in significant mobilization of As into the hydrogeological environment. **Concern (2)**: That the drilling mud, used for horizontal directional drilling (HDD) under water courses, would become contaminated with particles of naturally-occurring As-enriched rock and the mobile fractions of As may potentially contaminate the environment. Also, that the As-enriched rock-mud mixture may require handling and disposal as a hazardous waste class.” This statement is categorically wrong. There are three major concerns. Missing from this list and ignoring Prof. Onstott’s major concern, is the continual release of As from the fine-grained crushed rock surrounding the pipeline into the encompassing ground water. This leaching experiment fails to address the As mobilization by the pipeline construction and operation primarily on two points.

1. *Grain size of shattered rock was increased above the normal grain size thereby reducing the As release rate of the leaching experiment.* The investigator selected coarser grain sizes of their 6 samples (9.5 mm diameter for the 2” column and 38.1 mm diameter for the 6” column) than they had used in previous experiments (0.177

mm diameter) for the standard EPA acid mine drainage test because PennEast Pipeline claimed that the grain size of the backfill will be 1 to 30 cm. The piles of excavated bedrock, crushed bedrock, drilled and blasted bedrock and soil that will exist along the trench, the ditch spoils (see Fig. 1, from Figure 1E FERC EIS), are not sieved and will contain a large fraction of grain sizes much smaller than those used in the leaching experiment (Fig. 2). The experiment therefore underestimates the surface area available to leaching and thus underestimates the leachability of the “ditch spoil” close to the pipeline. According to PennEast Resource Report 1

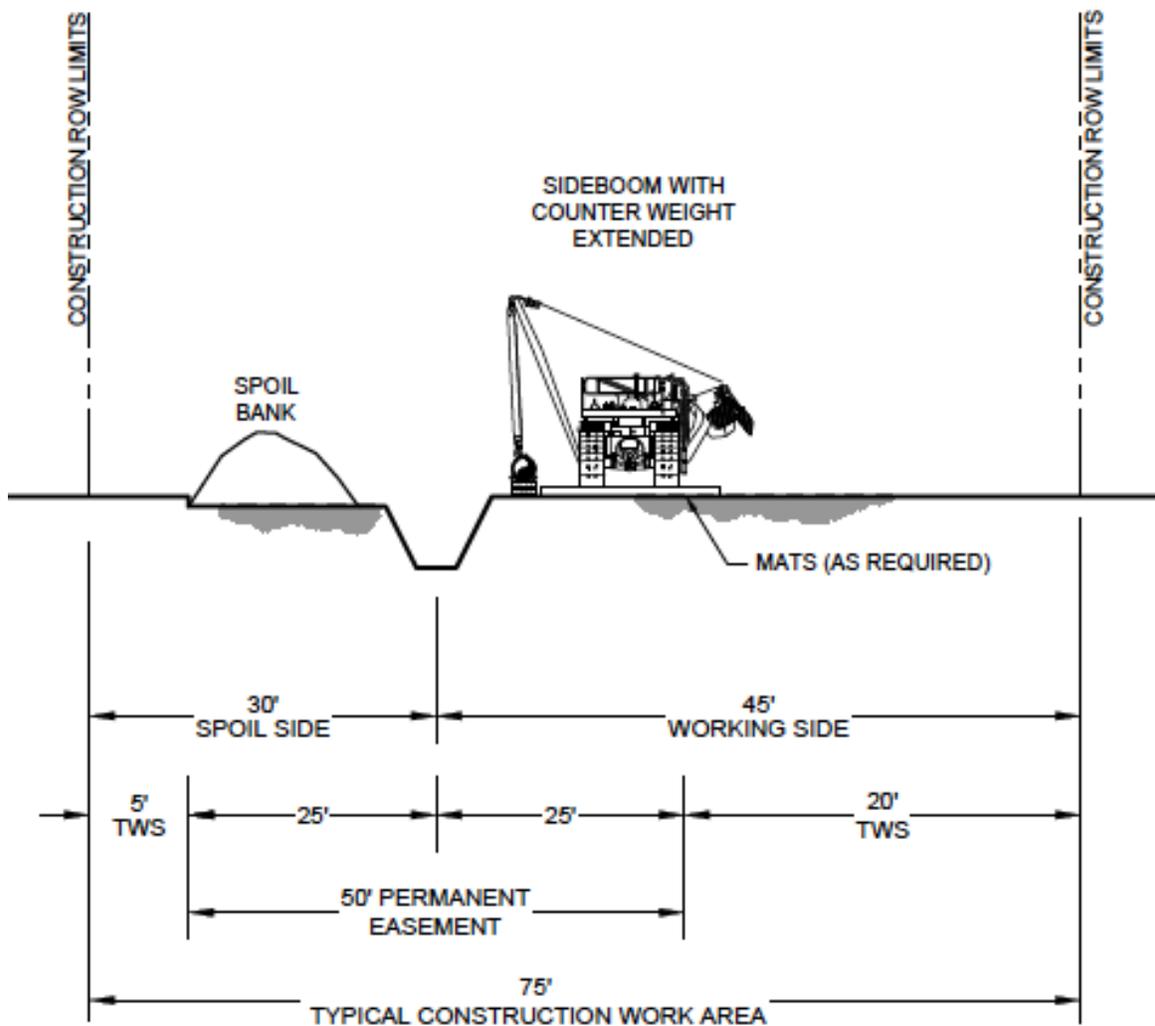


Figure 1. Cross-section of pipeline construction for wetland crossing from FERC EIS.

(Pipeline and Project. FERC Docket No. CP15-158-000), “A bedding layer of rock-free “pad dirt” is placed first to protect the pipe and coatings” (p. 68). Thirty centimeters diameter rock material is not rock-free. If the intention is to use 1 to 30

cm size rock chunks as the pipeline padding, then the pipeline is at serious risk of deformation and leaking over its operational lifetime, possibly leading to explosions. If, on the other hand, PennEast plans to screen the ditch spoils (trench soil), then the grain size of the materials padding the pipeline are finer grained than used in the leaching experiment. This means that the leaching experiment underestimates the As release rate of the backfill padding the pipeline.

2. *The investigator chose an EPA assay for acid mine drainage, which minimizes As mobility.* This assay was conducted in a mostly dry aerobic experiment that produces arsenate that is retained at pH conditions less than 7 by ferric iron oxides (Dixit and Hering, 2003), particularly the HFO produced during pyrite oxidation. This assay was then treated as a kinetic experiment, knowingly ignoring the redox nature of the As species, especially the mobility of As at neutral pH, under hypoxic (low-O₂)



Figure 2. Transco-Leidy Expansion showing ditch spoils adjacent to take off site for HDD located in the Passaic Formation shale. Note the abundance of fine-grained muds (mud cracks) and roots (organic carbon). Also note the drilling mud color and how the drill cuttings are filtered out.

and water saturated conditions, and the microbial processes that are responsible for the As redox chemistry and reductive dissolution of ferric oxides. Although

anaerobic conditions are dismissed in the HMM/Solution Geosciences Report as simply pertaining to “areas where significant amounts of organic contamination (leakage from a landfill for example) are transported in groundwater” (p.15 of HMM/Solution Geosciences Report), these are the conditions that will exist beneath the ditch spoils in the wetlands being crossed (see Fig. 1). These conditions will also exist along the pipeline after it is buried (organic-rich soil mixed in with pulverized arsenic-rich bedrock, epoxy coating leakage, and natural gas leakage and natural dissolved organic carbon (DOC), since the water table is above the pipeline in the As-rich formations being crossed by the pipeline (see below). Therefore the EPA method 1627 for predicting acid mine conditions is not relevant, underestimates the As mobility under these conditions and does not address Medha Kochar’s or the FERC’s initial requests nor the comments submitted to the FERC by Prof. Onstott.

3. *HDD leaching experiment is both inadequate and the results misrepresented.* The investigator admits that the assay procedure that they utilized, TCLP, is not directly applicable to rock-mud slurries (p. 32 of the HMM/Solution Geosciences Report). The EPA Publication SW-846 and the Federal Title 40 are irrelevant to the concern Prof. Onstott stated about the drilling mud frack-out. The experiment fails to provide the necessary data because it did not include any samples of the Lockatong Formation, which is the formation being drilled at Lockatong Creek and which is much harder than the Passaic Formation. The experiment was only run for 18 hours. The HDD proposed for Lockatong Creek will take much longer than 18 hours. It is not even close to the weeks duration required for HDD over a distance of one mile for a 36” diameter pipeline. The result from sample B-44 is irrelevant because its arsenic concentration was not determined, therefore we cannot calculate the rate of arsenic release as a first or second order process where the initial concentration is required. Only one time point is collected so we can only crudely estimate how much arsenic will be lost to the drilling mud filtrate during the course of drilling. It is disturbing that in the two measurements made during this assay the As released in the presence of the bentonite mud (41.4 ppb) was twice as high as that produced by DIW (18.8 ppb) and the author fails to explain why this occurs. Furthermore the frictional heating at the bit/rock interface will likely impact the rate of As release in the presence of the bentonite. The issue raised by Prof. Onstott is the danger for frack-out for the drilling fluid into the overlying surface water (e.g. of Lockatong Creek) where the New Jersey Surface Water Quality Standard (SWQS)(for As is only 0.017 ppb (N.J.A.C, 2011). This means that if only 100 liters of the drilling fluid filtrate penetrates into the overlying stream bed to the surface of the creek (out of at least a million liters of drilling mud that will exist in the borehole at Lockatong Creek) or wetland, it would have be diluted with at least 100,000 liters of stream water to stay below the As SWQS (assuming there is no As in the stream water). This will trigger the need for development of TMDLs (Total Maximum Daily Loads). If 100

liters of the drilling mud breaches to the surface, the situation will be far worse. Finally, the investigator concludes that the drill mud slurry is nonhazardous because its concentration is less than 5,000 ppm. If the point of the assay was to determine whether the drilling mud was less than 5,000 ppm (according to EPA Publication SW-8), then why perform it on rocks that only have 6 ppm in them? Obviously the mud slurry would be less than 5,000 ppm.

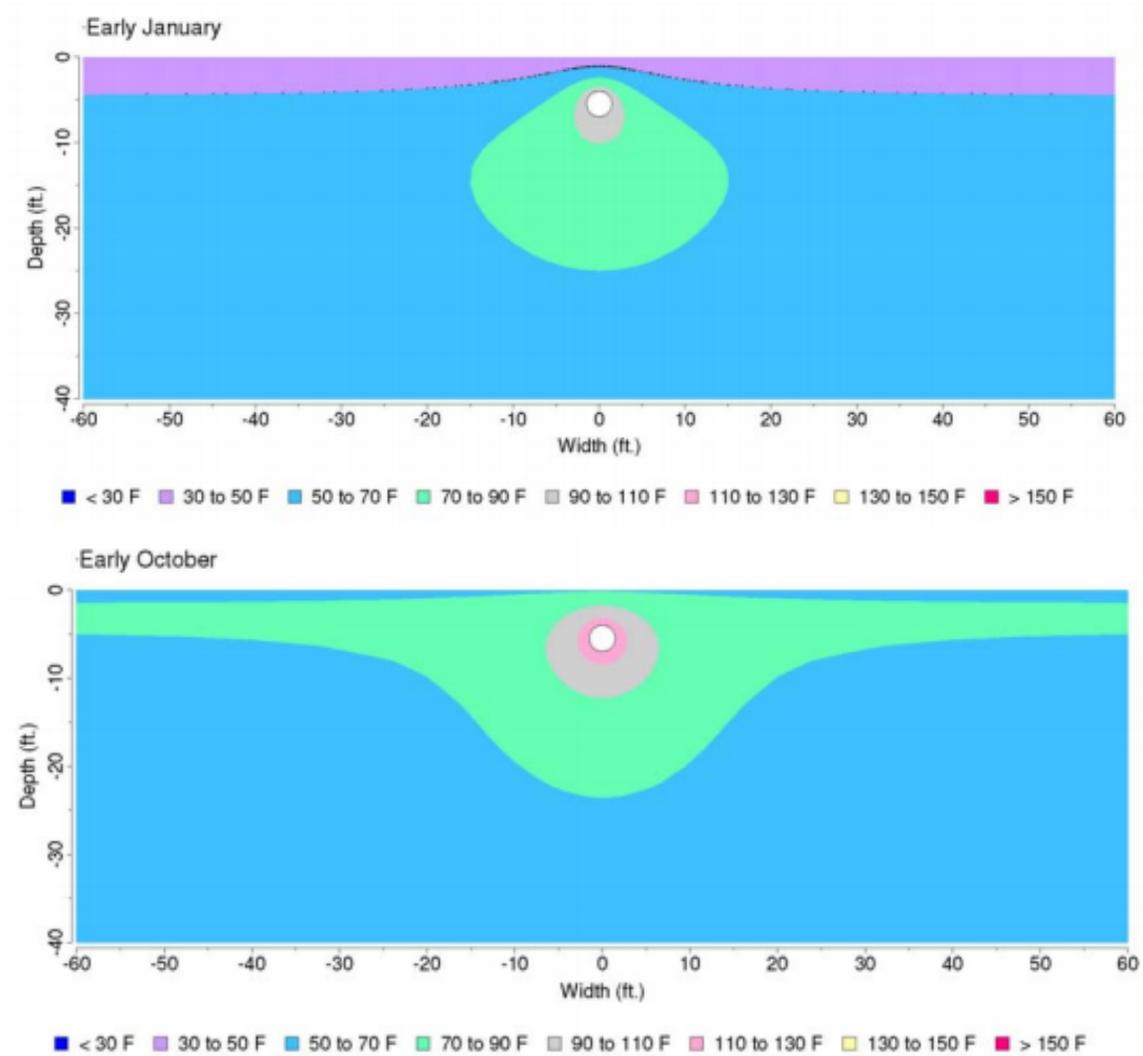
Additional Specific Flaws in HMM/Solution Geosciences Report

4. *Reductive Dissolution of HFOs by Fe(III)-reducing bacteria* - The investigator claimed that the formation of hydrous ferric oxides (HFOs) will create a coating on pyrite that can sequester As molecules, and thus, limit their transport (p. 5). Yet again, his experiments were run in an aerobic environment, which is not a realistic representation of conditions after the pipeline is buried. HFOs are readily reduced by Fe(III)-reducing bacteria releasing the As, which limits their effectiveness (Lee, 2013). We point out that Fe(III)-reducing bacteria are common in soils and sediments, needing only development of reducing conditions to become active. Fe(III) reducing bacteria were dismissed because this pipeline does not cut through developed land-use areas, where leakage from a landfill may provide a carbon source to bacteria. We point out that this premise is incorrect, as the proposed pipeline route does run through both agricultural and residential areas. Furthermore, Fe(III)-reducing bacteria are commonly found in aquifers that are pristine and uncontaminated and utilize a wide range of organic compounds and dissolved H₂ (Lovley, 1997). We propose that these bacteria will be stimulated by the pipeline operation and that their activity is not dependent on the presence of landfills specifically. Reducing conditions (as above) can be associated with septic-system leach-fields, where inputs of nutrients (primarily organic carbon) promote the growth of reducing environments through microbial degradations of the organic carbon. These conditions, in turn, promote the growth of Fe(III)-reducing and As(V)-reducing bacteria in New Jersey studies (Barringer et al., 2010; Barringer et al., 2011; Mumford et al., 2012; Mumford et al., 2015). Numerous other studies exist worldwide for instances of As mobility. Thus, bacteria can reduce the Fe(III) in HFOs, releasing adsorbed As(V). Bacteria can also reduce As(V) during their metabolic processes, thus putting it into the mobile As(III) form (Serfes et al., 2010).
5. *Time duration of the experiment was too short for determining important microbial processes that release As* - The time frame of the experiment (12 weeks) was likely too short to see relevant bacterial communities grow. Additionally, the use of deionized water (DIW) in experiment may have stunted or slowed bacterial growth and reactions insofar as no growth stimulus was supplied, and the fluid medium

(DIW) does not replicate actual aqueous conditions in the subsurface. The rate of As release could possibly increase after 12 weeks, were microbial communities to develop that could harness energy from materials in the columns. But, as a result of the conditions imposed on the experiments, the experimentally determined release rates for As are underestimated because they do not simulate actual conditions under which As is commonly mobilized from geologic materials. Given that, it is obvious that, even under the conditions of the experiments, substantial amounts of As were mobilized from the rock fragments to the surrounding DIW.

6. *Temperature of the experiment was kept low reducing the rate of As release.* The investigator claimed that “the trench environment will be generally warmer than the surroundings” (p. 19 of of HMM/Solution Geosciences Report); however, the experiments were all run between 20-25°C (68-77°F) (Appendix A of HMM/Solution Geosciences Report). The cause of the warmth is the frictional heat generated via gas flow through pipe. The TransCanada Pipeline, LP created a comprehensive study of how oil pipelines will affect soil temperature along its proposed route from Montana to Texas (TransCanada Pipeline, 2009). Their finding show that regardless of location, it is not uncommon to get temperatures above 100°F within a five foot radius of the pipeline during the summer. These elevated temperature regions become larger and warmer as the analysis moves from Montana to Texas with increasing Mean Annual Surface Temperature (MAST). According to a comparison of MAST in New Jersey (MAST of 55°F), Pennsylvania, and the six states included in this study, the PennEast pipeline will likely encounter conditions similar to those modeled in Kansas or Nebraska. In both Kansas and Nebraska, soil temperatures between 100-130°F are encountered within a few feet of the pipeline, and conditions between 90 and 110°F are encountered within a radius of up to ten feet from the pipeline (Figures 3-4). The frictional heating due to oil may be higher than that of a gas pipeline due to the greater viscosity. An analysis on a natural gas export pipeline in Norway, however, showed similar results (Oosterkamp, 2015). This study modeled soil temperatures using both conduction and conduction/convection, and calibrated this model using temperature sensors surrounding the pipeline which showed an average annual soil surface temperature of 47°F. The results revealed that the temperatures 5 cm from the pipeline were in excess of 80°F during an average month (Figure 5), or ~30°F higher than the ambient temperature. Logically, these temperatures would be even higher if the simulation were run only for summer months, or in a warmer climate that is more closely resembles the climate of the proposed PennEast route. For example, the annual average temperature in New Jersey is 55°F, therefore the heating should produce a temperature of 85°F. Thus, the 68-77°F temperature range used in leaching experiments does not realistically represent near-pipeline conditions. PennEast has not provided a comparable model

for the heating effects of its proposed gas pipeline nor an estimate of the gas temperature.



Figures 3 (top) and 4(bottom): TransCanada Pipeline, LP modeled temperature profile for Wichita, Kansas.

Higher temperatures accelerate both abiotic and biotic reactions rates. Thus, the leaching experiment should have been run under higher temperatures.

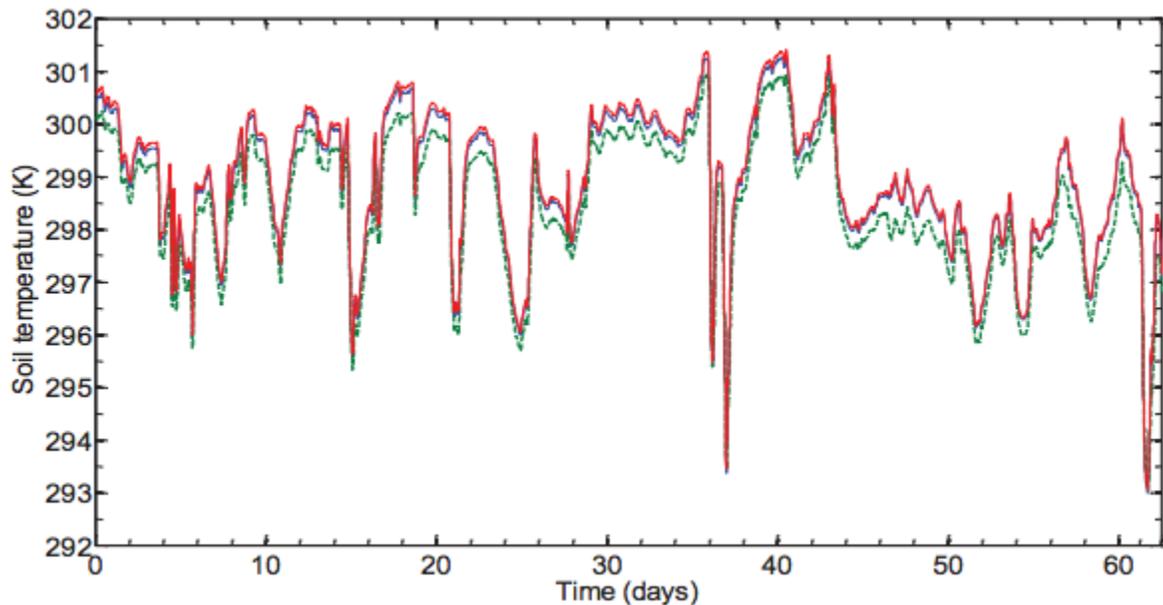


Figure 5: Annual average soil temperatures at location 5 cm from the Norway natural gas pipe with a gas temperature of 302 K. Dashed green lines indicate measured temperatures, while the red line is temperature predicted in the conduction model and the blue line is the temperature predicted using the natural convection model.

7. *Experiments should have used groundwater* - Competitive desorption was classified as “highly unlikely in the agricultural and undeveloped land-use areas surrounding the proposed trench transecting Hunterdon and Mercer Counties, NJ.” (p. 15). The investigator argues that competitive desorption from phosphate-containing fertilizers is on a local scale, and both sporadic and seasonal. However, according to publically available 2015 USDA crop data some of the proposed route cuts through known farming regions and preserved historical farms near water crossings, where the underlying rock is known to contain elevated levels of As (Figures 6-7). As in soils beneath old farms have been reported to be as high as 359 ppm (Shick, 2008). Competing ions like phosphate significantly lowers the retention sites for As on ferric hydroxides (Dixit and Hering, 2003) and as a result causes As to be released again (Serfes, 2010). Additionally, we point out that phosphate may already be present in soils and regolith in areas where the pipeline route crosses agricultural land (from fertilizers and animal manure) and residential land (septic systems). Therefore, disturbance of such materials can result in mobility of phosphate (note that, in the results of the New Jersey Piedmont study of Mumford et al. (2015), high concentrations of Phosphorous were present in the subsurface pore water with elevated As concentrations for the stream running through agricultural land. The experiment, therefore, should have used shallow groundwater or surface runoff

water from areas of appropriate land use to match with what the ditch spoils and backfill will experience. The use of DIW in leaching experiments designed to simulate As release under natural conditions would not be publishable in a peer reviewed scientific journal.

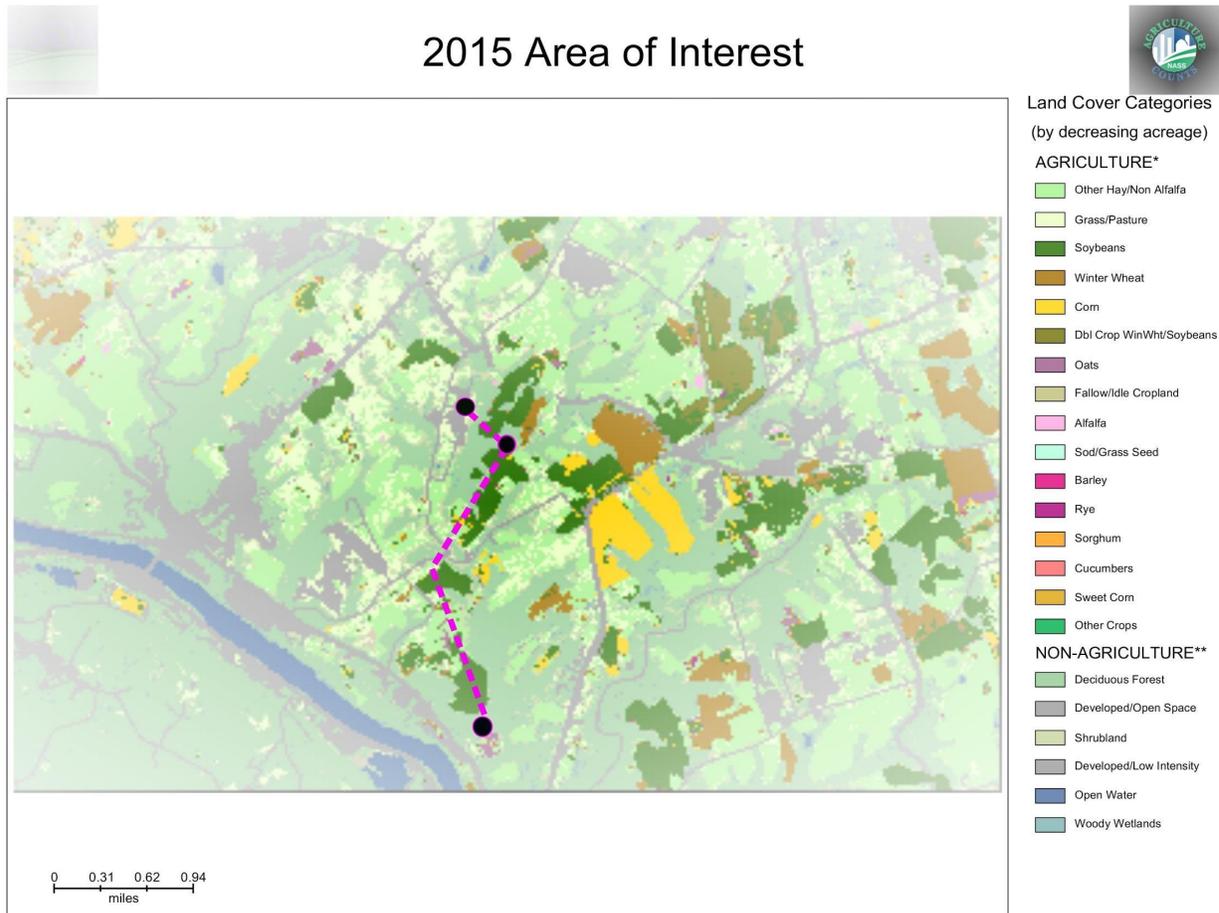


Figure 6: Farmland overlying Passaic Formation near Frenchtown, NJ shown with the approximate location of natural gas line and water crossings (circles). Dark green indicates soybeans. This farming area has alternated between soybeans, corn, sorghum, and winter wheat for the last decade, which is the extent of the high-resolution data available. Coordinates for points of interest are 40.544691°N, -75.061602°W, 40.561393°N, -75.060111°W, and 40.561393°N, -75.060111°W. Source: (Service, 2015).

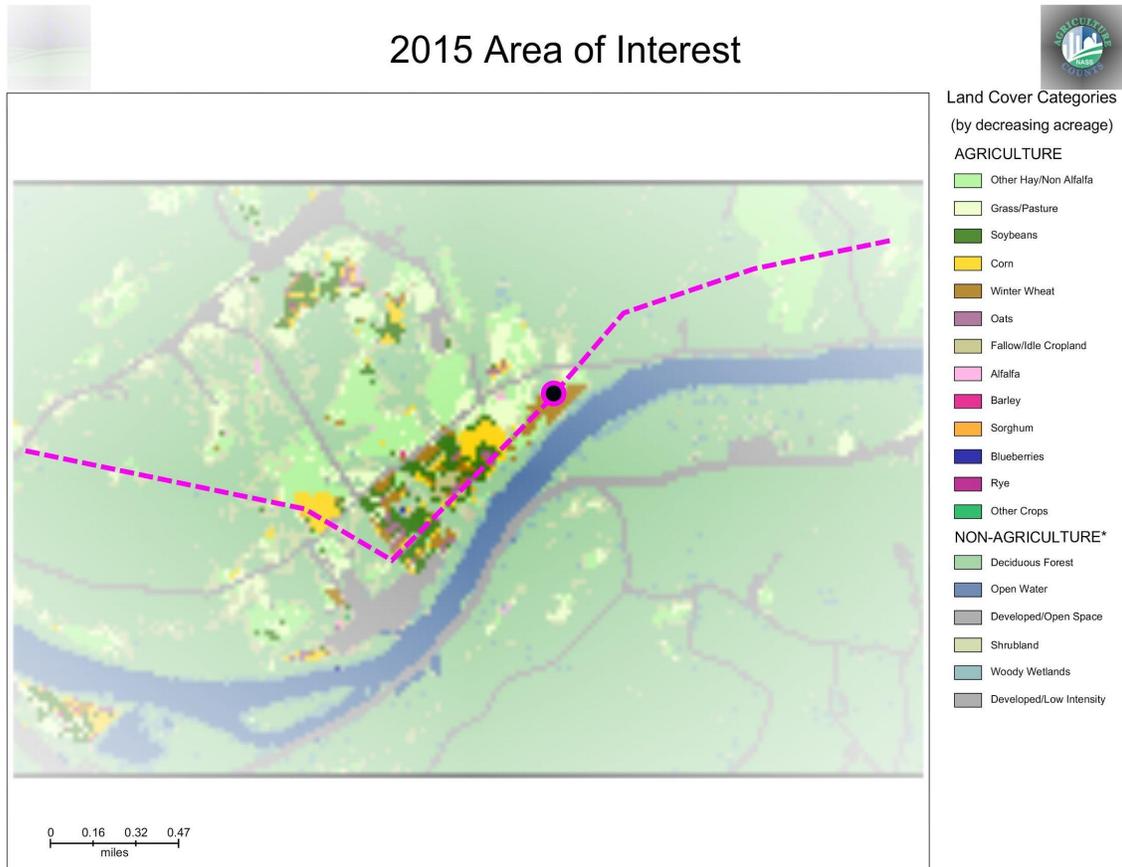


Figure 7: Farmland overlying Passaic Formation near Kintnersville, PA, shown with approximate location of natural gas line and water crossing (circle). Brown indicates winter wheat, while yellow and purple indicate corn and oats, respectively. This area has rotated between these three crops since at least 2008. Coordinates for the point of interest is 40.575454°N, -75.145143°W. Source: (Service, 2015).

- J. *Dissolved Organic Carbon (DOC) and Soil Organic Carbon (SOC)* - Deforestation or clear-cutting of forests (particularly deciduous forests) has repeatedly been shown to release organic carbon (An and Zheng, 2008; Farella et al., 2001; Jaiarree et al., 2011; Yimer et al., 2007). Thus, clear-cutting along the pipeline right-of-way poses a problem because this process will release organic carbon to soil pore waters and shallow groundwater, and organic carbon is a known driver of microbially produced reducing conditions. Numerous studies in As-elevated regions of southeast Asia have shown that organic carbon is a

control on As release (Anawar et al., 2013; Ayers et al., 2016; Buschmann and Berg, 2009; Lowers et al., 2007; Postma et al., 2007). Referring to the USDA crop time series, it is possible to trace the growth of hay regions and urban areas and corresponding deforestation of deciduous forests. Where these areas coincide with the proposed PennEast pipeline water crossings overlying As-bearing sediment, the results are recorded in Table 1. Since the soil organic carbon is degraded by bacteria (Postma et al., 2008), these areas are at risk for increased As mobilization for an indeterminate period of time due to microbial activity. Disregarding the deeply penetrating roots of trees, the average organic matter content of the sub-top spoil down to 60 cm depth in Hunterdon County is shown to range from 1.4 to 2.2 wt.%, with a relative enrichment near several sites where the underlying formation is the Lockatong Formation (Figure 8).



Figure 8: Lower portion of proposed PennEast route. The average weight percent organic matter of the top 60 cm is shown for the regions that also coincide with Passaic and Passaic gray beds. (Coordinates for these water crossings are 40.477483°N, -75.016178°W; 40.480504°N, -75.017107°W; 40.489883°N, -75.018487°W). Source: (Services., 2015).

Table 1: Areas that have been clear-cut since 2008.

Site Number	Latitude	Longitude	Year of change	Change in landscape	Past Crop
Lockatong 1C	40.352406°	-74.700265°	2013	Wetlands	Deciduous forest
Passaic 2	40.480504°	-75.017107°	2011	Road (Urban)	Hay/deciduous forest
Passaic 3	40.477483°	-75.016178°	2011	Road (Urban)	Hay/deciduous forest
Passaic gray bed 2	40.489883°	-75.018487°	2013; 2014	Pasture, then urban development	Deciduous forest
Passaic gray bed 3	40.536422°	-75.048734°	2011	Road (Urban)	Deciduous forest

8. *Depth of bedrock* - The investigator cited an average water table depth of 6-8 feet (183-244 cm), thus implying that the pipeline would safely be buried in the soil above the bedrock (p. 14 of of the HMM/Solution Geosciences Report). Using Web Soil Survey software, we were able to follow trends in bedrock depth along the extent of the proposed pipeline. In Hunterdon County, there are numerous areas where the bedrock is shallower than 100 centimeters, particularly where stream channels cross the proposed route, indicating that the pipeline would be deeply buried below the bedrock (Figure 9). This trend is important because burial of pipelines below bedrock represents the emplacement of a highly permeable pathway formed by organic-rich soil mixed with finely fragmented As-rich rock below a formerly low permeability barrier, and the creation of conditions under which As can be released from geologic materials to shallow groundwater that can discharge to areas streams.

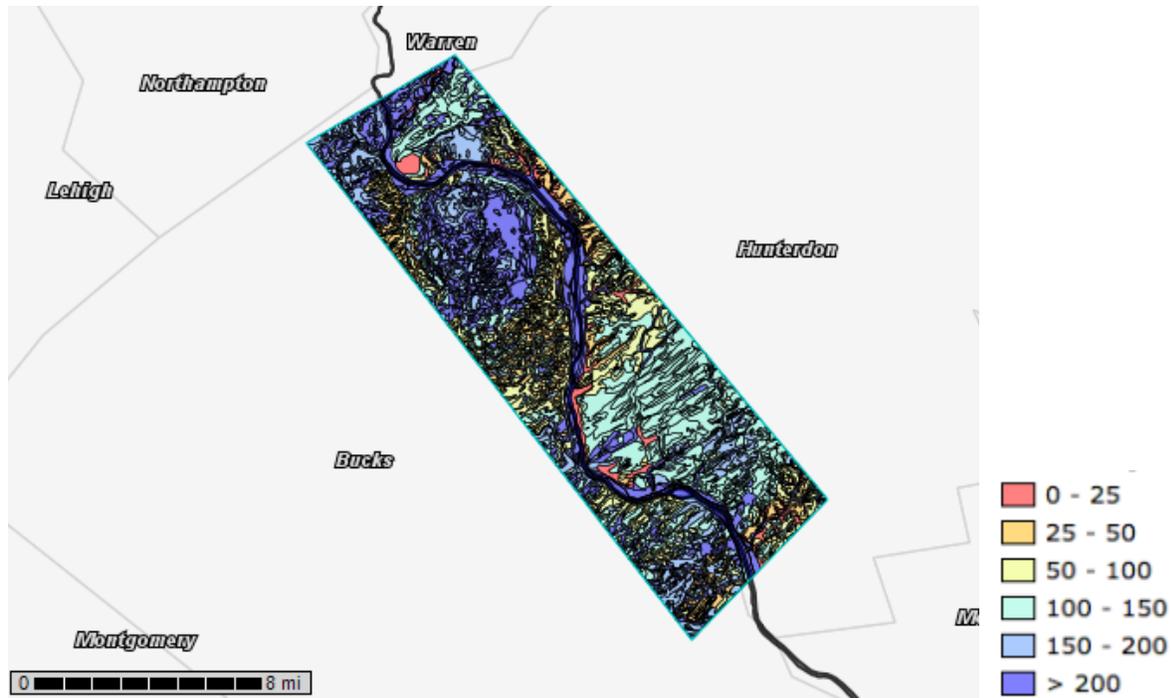


Figure 9: Lower portion of proposed PennEast route. The region with the shallowest depth to lithic bedrock (cm) also has several water crossings where Passaic gray beds are exposed. (Coordinates for these water crossings are 40.477483°N, -75.016178°W; 40.480504°N, -75.017107°W; 40.489883°N, -75.018487°W). Source: (Services.. 2015).

9. *Arsenic in deep versus shallow groundwater*- The occurrence of elevated As concentrations in water from deep wells rather than water from shallow wells was mentioned by the HMM/Solution Geosciences report, with the implication that only deep groundwater can be affected by As release from geologic materials. This refers back to the Serfes et al. (Serfes et al., 2010) discussion of the origin of the As in the 400 foot deep water supply well HW-6 in Hopewell, New Jersey. Serfes et al. (2010) found lower arsenic concentrations in shallower wells adjacent to the deeper well and thus inferred that the deeper well was not in communication with the shallower well. What the HMM/Solution Geosciences report fails to mention is that the CFC (chlorofluorocarbon) dates for the well water at both locations were 22 years, meaning that this inference is incorrect, and water does in fact move from the surface to depth over the time interval for pipeline operation. Furthermore, the observation that As is contributed to groundwater from the rock formation at depth does not mean that As cannot move to depth from shallower, contaminated locations. In a recent study by Raritan Headwaters of 14,000 wells within the North and South Branch of the Raritan Watershed, which overlies the Passaic Formation, As was found to have been increasing in concentration from 2003 to 2015

(MacDonald and Mitchell Thomas, 2016). Therefore, this argument is irrelevant to the issue of As contamination during operation of the pipeline. The more relevant issue is whether time-varying redox conditions occur in fine-grained As-rich rock and soil microbial cycling of As will occur that promotes the release and transport of As along the pipeline. Depths in the aquifer are not relevant. Mumford et al. (Mumford et al., 2015) showed that very shallow groundwater/sediment pore water can contain high concentrations of As that are derived from microbial action. We pointed out that the release of organic carbon from clear-cutting, soil disturbance, and creation of reducing conditions in the fine-grained packing around the actual pipeline, and the pipeline itself by the cathodic shield and leaching of epoxy coatings from the pipeline, all contribute to produce a biogeochemical environment in which existing HFOs can be effectively reductively dissolved, thus releasing adsorbed As. This reduction, coupled with microbial respiration can create mobile As forms in pore waters and groundwater. The mobile As phase will depend upon the pH in the presence of HFOs. If such pore water discharge to area streams, they can deliver As to stream water such that concentrations will exceed background levels for area streams, thus triggering the need for development of TMDLs (Total Maximum Daily Load). The background levels for As in Piedmont streams are probably < 3 ppb for unfiltered water samples, as shown by results in Mumford et al. (2015). Therefore, the As levels (up to 52 ppb) achieved in the oxidizing column experiments of (p. 32 of the HMM/Solution Geosciences report), far exceed expected background levels in area streams. In addition, because the disturbed materials in the pipeline trench will act as a conduit for meteoric waters, flow towards topographic lows—i.e., streambeds—should be enhanced. As reported by Serfes et al. (2010), increasing the water/rock ratio will significantly increase the As release rate (Fig. E18). In that experiment Serfes et al. (2010) showed that when the water/rock mixing ratio is 40, 4% of the total arsenic in Passaic mudstone could be released in just 16 hours! Such a ratio will not be exceptional for the highly permeable trench backfill, that sits below the water table on slopes entering and leaving water crossings. The HMM/Solution Geosciences report fails to mention the results of this experiment even though they use the same figure in their report (Fig. 7 of HMM/Solution Geosciences).

10. *Depth of water table* - Figure 10 shows the depth of the water table in Hunterdon County along the proposed route. According to PennEast Resource Report 1, all pipelines will be buried “with a minimum of 48 inches of cover, except where rock prevents this depth. In all other areas it will be installed with a minimum of 36-inches depth of cover” (p. 66). This depth range implies that for every location marked on Figure 10 as red or yellow, the pipeline will lie below the water table. Any gaining or “effluent” reaches of local streams (common in humid and temperate climates) are,

by definition, recharged by groundwater as they flow down gradient. Thus, As contamination in aquifers upstream due to input from the underlying pipeline would threaten both nearby aquifers and down gradient rivers. In this scenario, increased precipitation would not simply work to dilute As in groundwater, but rather, would create a movement of As-rich water from aquifers to down gradient streams and wetlands, thus potentially *increasing* As in the streams (Mumford et al., 2015).

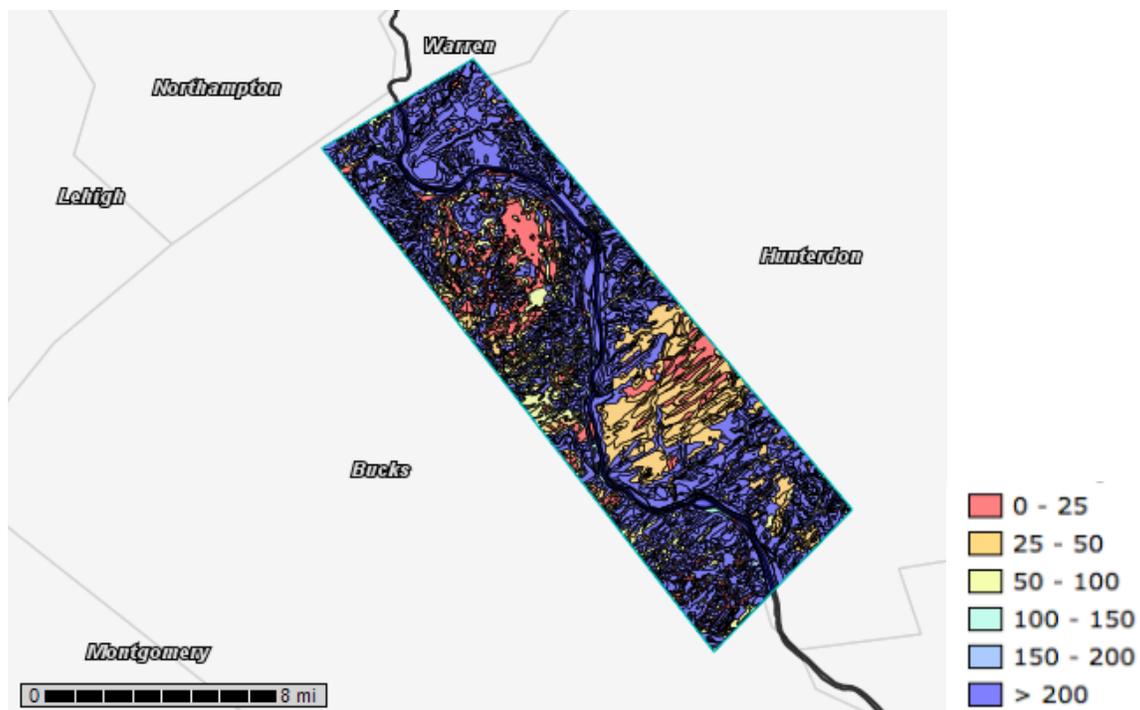


Figure 10: Lower portion of proposed PennEast route. The region with the shallowest depth to the water table (cm) has several water crossings where Passaic gray beds are exposed. (Coordinates for these water crossings are 40.477483°N, -75.016178°W; 40.480504°N, -75.017107°W; 40.489883°N, -75.018487°W). Source: (Services.. 2015).

11. *The dilution model uses only a one-time time input of trench arsenic thus minimizing the expected As contamination.* The dilution model described in Section 6.1 of the HMM/Solution Geosciences report does not take into account continued leaching of As into the aquifer over time, which was the central point of Prof. Onstott's submission to the FERC on February 26th, 2015. We have already shown that the leaching experiment performed by Solution Geosciences was biased in the grain sizes in order to reduce the As release, therefore the initial As trench concentration being diluted is an underestimate of the true value. The HMM/Solution Geosciences report does not even use its own kinetic data to estimate the rate of arsenic release over the long term. Finally we would have expected a groundwater flow model to

properly take into account reactive transport, permeability, porosity, and microbial activity. A dilution model based upon flawed kinetic parameters provides zero assurance against the potential As contamination resulting from operation of the proposed pipeline on a decadal time scale.

12. *Lack of pH measurements in EPA acid mine drainage assay test.* Conditions for pH of fluids in the assay used are not reported; therefore it is not known what the starting pH was in the experiments, whether it varied throughout the experiments, and whether concentrations of As in the leachate had any relation to pH of the experiment fluids. Thus it is not clear whether the pH environment of the areas surrounding the pipeline were duplicated. Natural stream pH's are typically greater than 7 in Piedmont water bodies, and shallow ground water only slightly less than 7 where As is microbially mobilized (Mumford et al., 2015). Groundwater pHs elsewhere have been measured at >7. If cement is used in the pipeline construction as water barriers, then the pH of surrounding pore waters is likely to increase, thus promoting desorption of As(V). Senior and Sloto (2006) effectively show how As in groundwater of Newark Basin aquifers increases as pH increases.
13. The HMM/Solution Geosciences Report mentions that the As concentrations in soils overlying bedrock can be particularly high, up to 359 ppm (Figure 19 of the HMM/Solution Geosciences Report) during excavation of the Investment Company Corporate Center Campus (Shick, 2008). This concentration is ten times the average concentration of the underlying bedrock and this soil will be utilized to pad the pipeline, thus increasing the arsenic contamination further. Although HMM/Solution Geosciences claims that this demonstrates the immobility of the As in unsaturated zones, they do not present groundwater As concentration data from wells around the construction site following the construction so they cannot conclude that the construction has not had any influence on the surrounding wells. These high concentrations of As in the soils are also alarming as they represent potential As contamination of wetlands and streams. **THESE HIGH ARSENIC CONCENTRATIONS IN SOILS AT DEPTH SHOULD BE RAISING RED FLAGS.** In a recent study by Raritan Headwaters of 14,000 wells within the North and South Branch of the Raritan Watershed, which is underlain by the Passaic Formation, As was found to have been increasing in concentration from 2003 to 2015 (MacDonald and Mitchell Thomas, 2016).

Appendix – Response to Specific Comments in in HMM/Solution Geosciences Report

1. On page 2 in the Executive Summary, the HMM/Solution Geosciences Report states the following:

“The results from the work presented in this report demonstrate that the pyrite in the Lockatong Formation black-gray argillite-shale rock samples tested, sequester rather than release As upon oxidation, thereby reducing the availability of mobile As. There was no evidence of ARD (Acid Rock Drainage).”

Acid Rock Drainage was never raised as a particular concern by Prof. Onstott and is not an appropriate test for determining the mobility of As under the conditions of pipeline operations.

2. On page 2 in the Executive Summary, the HMM/Solution Geosciences Report states the following:

“However, it has never been definitively demonstrated if the As in water from these affected potable wells is the result of near surface geochemical or deeper processes in the water-bearing zones that feed them. There are much data to support the latter.”

This statement is in direct conflict the results of the USGS publication by Gross and Low (Gross and Low, 2013) on the occurrences of elevated As concentrations in a survey of hundreds of wells within the Newark Basin of Pennsylvania are correlated with anthropogenically contaminated sites. Clearly surface activities do influence groundwater As concentration in a fracture-flow aquifer like that of Newark Basin. In a recent study by Raritan Headwaters of 14,000 wells within the North and South Branch of the Raritan Watershed, which overlies the Passaic Formation, As was found to have been increasing in concentration from 2003 to 2015 (MacDonald and Mitchell Thomas, 2016).

3. On page 2 in the Executive Summary, the HMM/Solution Geosciences Report states the following: “The results from the work presented in this report demonstrate that the pyrite in the Lockatong Formation black-gray argillite-shale rock samples tested, sequester rather than release As upon oxidation, thereby reducing the availability of mobile As. There was no evidence of ARD (Acid Rock Drainage).”

Acid Rock Drainage was never raised as a concern by Prof. Onstott (See Point 2 above).

4. Section 5.3. p. 28. Princeton University Campus building stone - The investigator performed an “experiment” on the Princeton University campus, where he observed a low degree of weathering and HFOs associated with pyrite oxidation on Cleveland Tower, a building made of rock from the Lockatong Formation. He claimed that this is evidence of “an intrinsic resistance to readily weather and decompose”.

This “experiment” fails to take into consideration the high levels of water saturation, anaerobic conditions, elevated temperature that surround the buried gas pipeline buried in pulverized Lockatong Formation. Not only is such an “experiment” irrelevant to the weathering of pulverized material, in a peer reviewed scientific journal this argument would be immediately rejected.

5. Section 5.2, P. 27

“A calculation of rock fragment sizes that would be produced during blasting in this rock (blasting will be applied where needed in the field during the trench excavation) using the updated Kuz–Ram model as per Cunningham (2005) indicated that the particle sizes will be even coarser (10 mm to 300 mm) and that at least 80 percent of the fragments will be greater than 25 mm with an average fragment size of 61 mm. Based on the larger PSDs calculated for blast related rock fragmentation in this rock versus that used in the 6-inch leach test columns it is predicted that the actual maximum aqueous arsenic concentrations derived from these materials in the non-imported excavation backfill rock materials will be much lower during the labile and subsequent reaction phases.”

I am surprised that the investigator could not find the time to collect a triplicate sample of ditch spoil from an ongoing pipeline construction project (the Transco-Leidy Expansion) located in Princeton, since he was obviously in the area. As shown in Figure 2, the ditch spoils associated with the Transco-Leidy contains plenty of mud/silt size particles, not dominated by inch size chunks. Instead the investigator uses a theoretical relationship derived from a conference paper that has so many unqualified variables as to make any calculation of mean size, let alone the particle size distribution (PSD), completely unreliable. The investigator does not report the values of the variables, e.g. Rock Factor, Powder Factor, Explosive Mass, etc., that he used in the calculations, nor the justification for the variables. The main point of (Cunningham, 2005) was to advise against the application of this type of application. It provides no PSD, the investigator made no serious effort to measure a PSD of ditch spoil and the investigator made no effort to measure the surface area of the sieved chunks that he utilized in his experiment. All of these factors would not be acceptable in a peer-reviewed scientific publication.

Conceptual Assumptions in the Trench Environment:

- 1) The trench environment will generally be humid with wetted rock surfaces
- 2) The trench environment will be generally warmer (heat generated via gas flow through pipe) than the surroundings; and therefore, have a higher vapor pressure and soil gas to atmosphere venting than the vegetated surrounding field/forested habitats. Soil gas in those habitats will have $CO_2 \gg$ atmospheric due to organic decomposition and will continually flow toward, into, and up and out of, the trench.

Therefore, conceptually, we believe EPA 1627 approximates the conditions expected in a trench environment in the area of concern.

This assumption is invalid because the water table depth for much of the As-rich region traversed by the pipeline in Hunterdon County and in water crossings elsewhere is less than 50 cm (Figure 9).

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Document Content(s)

Motion to Intervene - Arsenic and PennEast Pipeline.PDF.....1-25

Exhibit B

Additional Arsenic Exposure to Groundwater from PennEast Pipeline

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Summary

Contamination of groundwater by arsenic (As) of geologic origin is now recognized to be a widespread problem. The mechanism by which As is released from geologic materials has been extensively studied; the contamination is known to result from microbial activities that are stimulated by organic carbon or reduced equivalents (e.g. H₂), both natural and human-induced. Fe³⁺-reducing bacteria are one of the most important groups of microbes capable of releasing As from geologic materials. These bacteria do this by transferring electrons to ferric (Fe³⁺) oxides and hydroxides, thus solubilizing the iron (Fe²⁺) and releasing adsorbed As. We have determined from a 2D reactive/transport simulation of this process that the proposed PennEast pipeline when emplaced in the Passaic Formation could stimulate similar processes simply through long-term gas leakages. The model results indicate that the resulting As groundwater plume may reach hundreds of meters over a decade time scale. The examination of existing well data suggests that we may be seeing evidence of this impact associated with the Algonquin pipeline, which has been in operation for ~60 years. We conclude that the FERC DEIS has seriously underestimated the potential environmental risk to groundwater in Hunterdon County. This report also clearly demonstrates that the mitigation strategy proposed by FERC in its DEIS is seriously inadequate as it does not consider the time or distance scale over which the contamination can occur. Monitoring for potential As contamination cannot just be restricted to the construction phase, but needs to be extended over decades. PennEast also has to be prepared to either pay for the purchase and the replacements of As filtration systems for decades or to drill new water supply wells that access aquifers that do not contain As. The high As concentrations in the Newark Basin aquifer combined with its low effective porosity and its fracture-induced cross flows makes it especially vulnerable to hydrocarbon transmission and storage lines buried in the As-rich bedrock and soil. Predicting the environmental risk of the As migration will be exceedingly difficult without much more thorough investigations that combine hydrological testing with geochemical and microbial assays. These studies need to be performed before granting 401 permits to PennEast and on a location-by-location basis. The outcome of these studies will likely indicate that PennEast needs to select an alternative ROW that does not cross a sole-source aquifer in As-bearing rock units.

Introduction

FERC states on page 4-280 of the DEIS that "*There is a possibility that the proposed Project, together with others such as the recently completed Northeast Supply Link*

Project's Stanton Loop, could result in additional arsenic exposure to groundwater in the Hunterdon County area." The amount and spatial extent of As exposure and the mechanisms responsible for this exposure and how it could be mitigated are not stated in the DEIS. In February 2016 we outlined the processes by which natural gas transmission lines cutting through As-rich rock units can cause the release of As into groundwater. In this report we revisit the mechanisms by which the PennEast pipeline could contaminate groundwater in Hunterdon County with As, and present the results of a 2D reactive transport model of the biogeochemical processes to determine the time scale and spatial scales over which such contamination could occur.

In shallow, oxic, aquifers hosted by As-bearing rocks the As is frequently adsorbed onto ferric iron, Fe^{3+} , oxyhydroxide mineral phases. Organic carbon introduced into the aquifer by contamination creates reducing or anoxic conditions. Under these conditions Fe^{3+} -reducing bacteria oxidize the carbon (or reduced equivalents) while simultaneously reducing the Fe^{3+} to Fe^{2+} and, thereby, dissolving the iron oxyhydroxide mineral phases. This microbial activity releases Fe^{2+} and As into the groundwater and raises the pH. At higher pH As desorbs from the iron oxyhydroxide mineral phases. The release of As into groundwater by the microbial reduction of iron oxyhydroxide minerals proceeds via two mechanisms, reductive dissolution of the mineral phases and desorption of As from the iron oxyhydroxide mineral phases (Smedley and Kinniburgh, 2002). The reductive dissolution of As-rich iron hydroxides is considered the cause of naturally occurring high As concentrations in groundwater in Bangladesh (McArthur *et al.*, 2001) and in the shallow aquifers in the Midwestern U.S.A. (Erickson and Barnes, 2005a; Erickson and Barnes, 2005b; Kelly *et al.*, 2005; Root *et al.*, 2010; Thomas, 2003; Warner, 2001). The same mechanisms for As release into groundwater has been reported for aquifers in the United States and Europe contaminated by landfills (deLemos *et al.*, 2006) and petroleum leakages (Burgess and Pinto, 2005; Ghosh *et al.*, 2003). The problem of hydrocarbon leakages from pipelines stimulating microbial mobilization of As from the mineral matrix into the groundwater is so significant that the American Petroleum Institute published a manual on the topic (API, 2011).

The roles of microorganisms in As mobilization in the Newark Basin, either naturally or in environments contaminated by organics, was not explored by Serfes *et al.* (Serfes *et al.*, 2010), but was mentioned as a topic for future work. The HMM/Solutions Geosciences LLC report (Shah and Starcher, 2016) to PennEast that was submitted to FERC in May of 2016 states on page 20 that "Hematite, the As bearing mineral in the Passaic red strata is not similarly affected by microbes in these environments." This is incorrect; the report fails to acknowledge that reductive dissolution of hematite by Fe^{3+} reducing bacteria has been known for at least two decades (Bonneville *et al.*, 2004; Lovley *et al.*, 1998; Weber *et al.*, 2006).

One of the best-characterized sites where these processes occur is an aquifer located near Bemidji, Minnesota, that was contaminated by ~2 million liters of crude oil when a pipeline ruptured in 1979. In 2014, Cozzarelli *et al.* (Cozzarelli *et al.*, 2016) found that a hydrocarbon plume extended 200 meters away from the pipeline, and an As plume reaching concentrations as high as 230 ppb extended 100 meters from the 35 year old

breach. Cozzarelli et al. (2016) also demonstrated that the As originated from the sediment through release by microbial Fe^{3+} reduction. From their reported As concentration in the sediment of only 2.5 ppm, and an aquifer porosity of 30%, and a matrix density of 2.65 g/cm^3 (density of quartz), they estimated a maximum As concentration in the water, if all of the As was released to the aqueous phase, of 14,840 ppb (Cozzarelli *et al.*, 2016). Cozzarelli et al. (2016) concluded that only 0.15% of the As in the sediment released into the groundwater can account for the 230 ppb. Their conceptual model for the As cycle in the plume includes trapping of the As at the outer edge of the hydrocarbon plume (Figure 1). More importantly, they conclude that over time

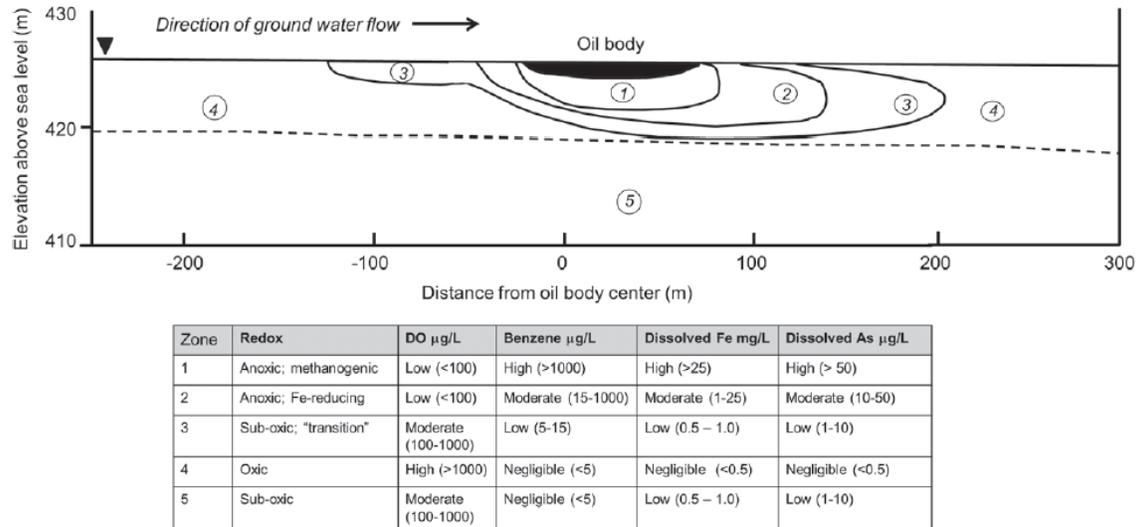


Fig. 1. From Figure 7 of Cozzarelli et al. (2016). Zone 2 where Fe^{3+} reduction occurs leads to moderately high As concentrations (10-50 ppb). In sub-oxic Zone 3 the As concentrations will be 1-10 ppb as As is absorbed onto the sediment.

that the As plume will shift down gradient. Bekins et al. (Bekins *et al.*, 2005) using a groundwater reaction/transport model showed that as groundwater migrated at $\sim 20 \text{ m/yr}$, the benzene will migrate at 0.3 m/yr , but the high Fe^{2+} plume migrates at $\sim 3 \text{ m/yr}$, rereleasing the As into the groundwater.

Estimates of the leakage rates of CH_4 from natural gas pipelines into the atmosphere range from 1 to 3% of the total transported volume (McKain *et al.*, 2014). The proposed PennEast pipeline will transport 1 billion cubic feet per day. If only 0.1% of that CH_4 leaks into groundwater of the surrounding trench, it represents an organic carbon flux equivalent to 300,000 grams of carbon/ m^2 -year. This is 100 times greater than the Net Primary Production of a forested area in New Jersey, which is about 2,500 grams of carbon/ m^2 -year (Costanza et al., 2006). Such a leak rate would produce the equivalent of a Bemidji-size organic source in approximately one week. The CH_4 leakage combined with the additional carbon load for soil organic carbon of the trench backfill, the leaching of organic carbon from the protective epoxy coatings and the electron flow from the

cathodic shield into the trench represent a potent source of reducing power that can sustain microbial Fe^{3+} reduction and As release into groundwater. In the case of the cathodic shield, H_2 gas will be generated in the trench water surrounding the pipeline (Kean and Davies, 1981). This dissolved H_2 is readily consumed by bacteria as an alternative energy source to organic carbon (Onstott *et al.*, 2010). Cathodic shields also increase the pH of the water surrounding the pipeline to 9 to 13 (Norsworthy, 2009), which effectively desorbs As from any iron oxyhydroxide mineral phases. For this report we focused on modeling only the impact of CH_4 leakage into the groundwater, how it would stimulate the coupling of microbial Fe^{3+} reduction of the shales in the Passaic Formation, and how this would impact the release of As into the groundwater and its subsequent transport.

Modeling Approach

Groundwater flow in the Newark Basin aquifer occurs primarily through discrete water-bearing zones, WBZ's, parallel to the strike and dip of bedding, whereas groundwater flow perpendicular to the strike is restricted. This produces a strong anisotropy to the groundwater flow field. Because the proposed PennEast pipeline is crossing the strike of the Newark Basin sedimentary rock units, it crosses the recharge zones for many of the WBZ's in Hunterdon County. Many of the streams at the higher elevations being crossed by the PennEast pipeline, such as the Lockatong and the Wickecheoke Creek, are losing streams, i.e. the stream water recharges the groundwater in the WBZ's they cross, during the summertime (Authority, 2009). As a result of this design, the impact of any pollutant entering the WBZ through the recharge zones crossed by the highly porous and permeable pipeline trench will have maximum dispersal down gradient to water-supply wells in Hunterdon County. The high yielding WBZ's formed by dissolution fracture layers are capable of transporting groundwater pollution for thousands of feet in short time intervals (Herman, 2010) and thus water-supply wells are highly susceptible to As released at the pipeline trench.

Previous hydrological models of Newark Basin rock units have treated the WBZ's as a uniform porous medium (Yager and Ratcliffe, 2010) even though water flow is clearly influenced by fractures (Herman, 2010). Carleton *et al.* (Carleton *et al.*, 1999) used a numerical solute-transport model SUTRA to simulate the groundwater flow through the water bearing zones in the Passaic Formation of the Newark Basin. The model was calibrated by data collected from pumping tests and doublet bromide tracer tests performed in the Passaic Formation at the Stony Brook-Millstone Watershed Association 250-ha nature reserve. Carleton *et al.* (1999) determined that the hydraulic conductivity was 7 m/d parallel to the strike of the bedding plane fractures, 3 m/d down dip and only 4×10^{-5} m/d normal to the bedding plane fractures that dip at $\sim 20^\circ$ to the north. Models of the Bromide tracer tests yielded a best-fit effective porosity of 0.14% (volume of

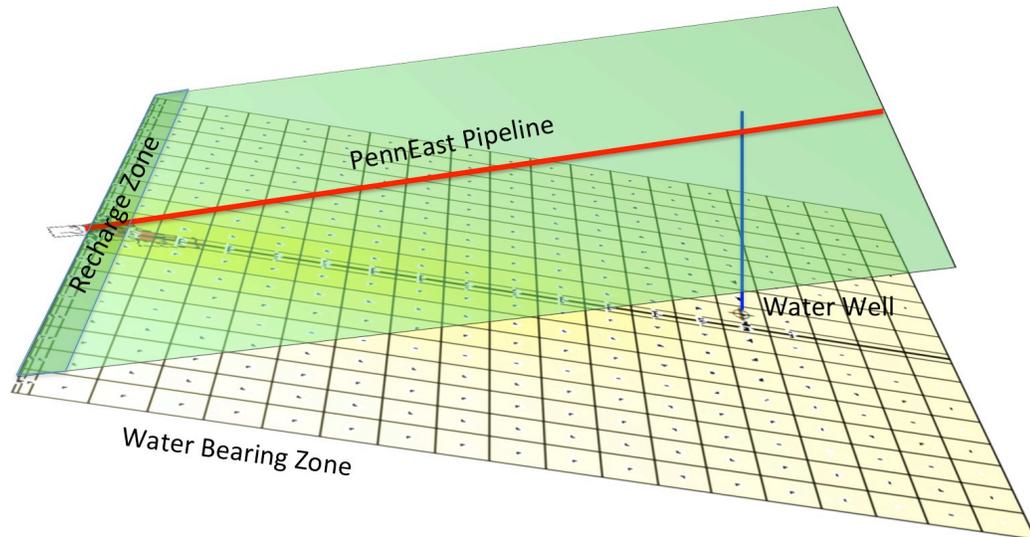


Figure 2. Diagram of 2-D media used in model to simulate transport of arsenic from intersection of PennEast pipeline with water bearing zone. Yellowish color in middle of the domain represents an arsenic transport plume migrating with recharging groundwater entering the WBZ.

water/volume of rock). Note that the matrix porosity was 4 to 5% and the matrix permeability was 7.8×10^{-4} m/d. Given the same recharge rate, the water velocity through an aquifer with an effective porosity of 0.14% will be 30 times faster than the water velocity in an aquifer with an effective porosity of 4 to 5%. Given the same rate of As release from the mineral matrix, the As concentration will be higher in a lower porosity aquifer, because less dilution occurs (Cozzarelli *et al.*, 2016)(also see Figure E18 of Serfes *et al.*(Serfes *et al.*, 2010)). A larger scale 3D SUTRA numerical model of Newark Basin hydrology by Yager and Ratcliffe (2010) derived an effective porosity of 2% over multiple kilometers as constrained by $^3\text{H}/^3\text{He}$ dates of shallow groundwater. Using the multi-scale bromide tracer tests Carleton *et al.*(Carleton *et al.*, 1999) estimated a longitudinal dispersivity of 12.8 meters for their 183-meter injection test. Although the transverse dispersivity is normally assumed to be an order of magnitude less, larger values may be responsible of the bromide tail observed in the bromide break through curves (Carleton *et al.*, 1999).

Ground-Water Recharge for Hunterdon County, New Jersey

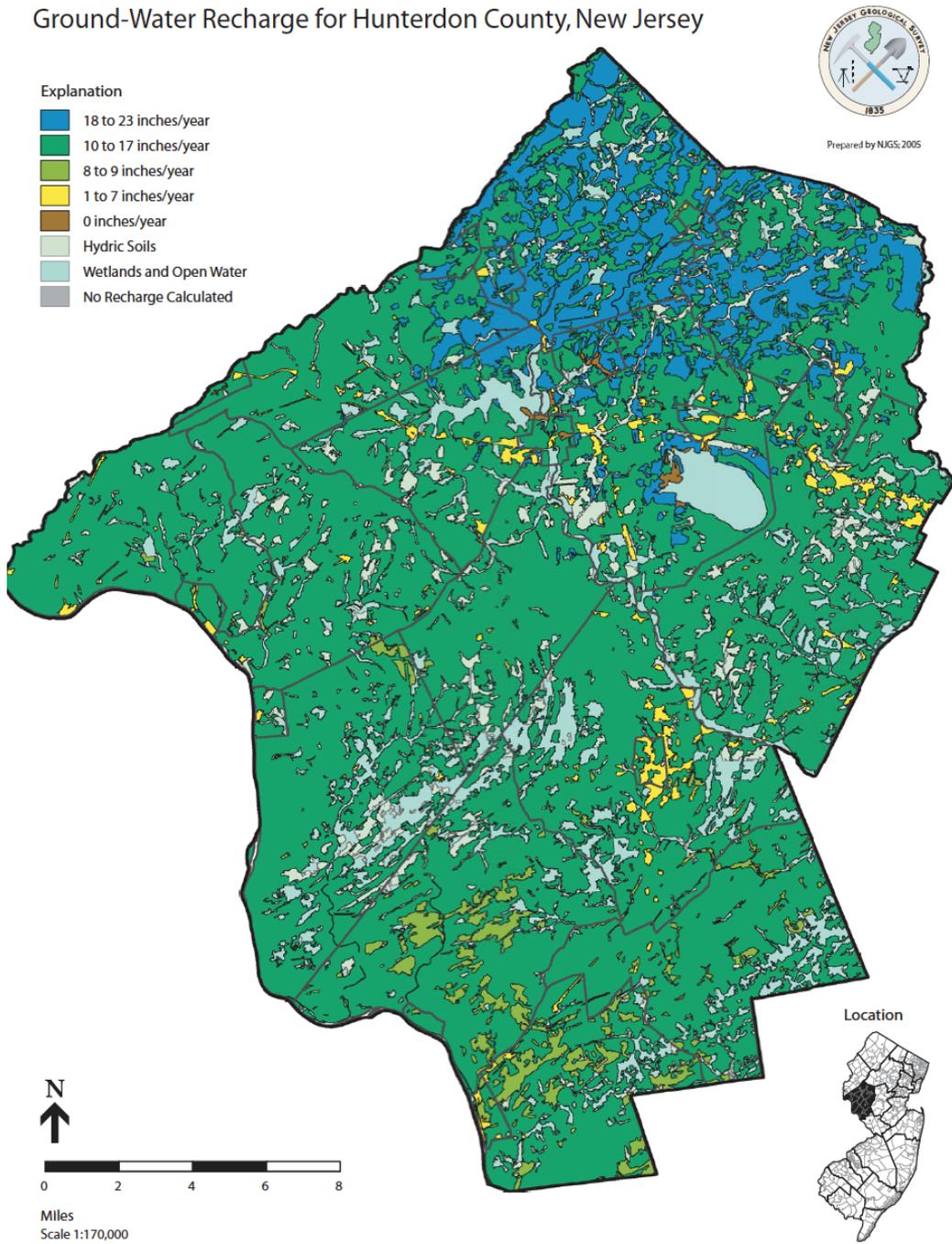


Figure 3. New Jersey Geological Survey 2005 map of groundwater recharge rates for Hunterdon County.

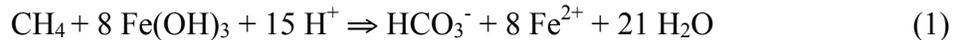
Physical Properties - A two-dimensional As reaction and transport implicit finite difference model was utilized. The two-dimensional medium was oriented in such a way that the pipeline trench was on the same side as the recharge zone of the WBZ (left side in Figure 3) and was 25 m thick. The recharge rate was varied from 10 to 20 inches/year as indicated by the Hunterdon County Ground-Water Recharge Map (Figure 3). The pipeline trench was represented by a 3x3 m node to include the trench and construction damage zone around the excavated trench, while the remaining nodes were comprised of 20x20 up to 50x50 m. Given the proximity of the site studied by Carleton et al. (1999) to the proposed PennEast pipeline ROW we felt justified in adopting the hydrological properties from above into our reaction-solute-transport model. The porosity of the media was varied in simulations to look at its impact on the fluid velocities and the As concentrations. Simulations were run with and without wells. The distance of the well from the pipeline was controlled by the distance along the Y-axis, and the distance along the X-axis is related to the well depth such that 330 meters distance corresponded to a 110 foot well depth.

Chemical Properties – We modeled the effects of As adsorption using a two layer surface complexation model with weakly and strongly absorbing sites. For our model we chose ferric hydroxide (or hydrous ferric oxide or HFO) as the absorbing mineral with surface densities of 0.005 and 0.2 moles of sorbing sites/mole of HFO for strongly and weakly sorbing sites, respectively. The specific surface area of the HFO used was 4×10^4 m²/mole of HFO. The equilibrium constants utilized for surface complexation are from Dzombak and Morel (1990)(Dzombak and Morel, 1990). This model exhibits a strong dependency upon the pH with arsenate not adsorbing as strongly at higher pH. We assumed a background As concentration in the groundwater of 2.5 ppb and equilibrated this with the HFO at an initial pH of 7.6 based upon the median ground water chemistry reports by Serfes et al. (2010). This yielded a total As concentration in the sediment of 2.3 ppm as absorbed As per 0.8 wt% Fe₂O₃. For the Passaic Formation, the Fe₂O₃ concentration ranges from 5 to 9 wt% and using a correlation factor of 2.3 (Serfes et al., 2010) this yielded an absorbed As concentration of 14 to 28 ppm.

Chemical Reactions – We simulated the release of CH₄ into the trench node at a rate estimated from assuming that only 0.1% of the CH₄ is leaking from the pipeline into the environment. This is equivalent to $\sim 10^{-8}$ moles of CH₄/liter-sec for a 25 meter long section of the pipeline. The CH₄ leakage from one small node into a larger domain simulates the dilution effect reported by HMM/Solution Geosciences report . The high porosity, high permeability trench represents an organic rich source that feeds microbial metabolisms in the WBZ even if we ignore the additional carbon load for soil organic carbon in the trench backfill, the leaching of organic carbon from the epoxy coatings, and the electron flow from the cathodic shield into the trench. For the simulations we varied the CH₄ leakage from $\sim 10^{-8}$ to 10^{-7} moles of CH₄/liter-sec.

As stated in the HMM/Solution Geosciences report (Shah and Starcher, 2016), certain microorganisms reductively dissolve HFO and this reaction will lead to As release. Not stated in the report is the fact that microbial Fe³⁺ reduction also increases the pH, which leads to As release. We, therefore, modeled this microbial reaction as a simple redox

equation defined by the following equation,



We treated this as a first order reaction with respect to CH_4 , but the rate of the reaction was modulated by the Gibbs Free Energy of the reaction. Unlike the CH_4 leakage reaction that was restricted to the pipeline node, this reaction was present in all spatial nodes of the simulation. As the Gibbs Free Energy of the reaction approached zero, the reaction rate approached zero (Jin and Bethke, 2003). The net reaction may, in fact, be performed by multiple species of bacteria, as opposed on a single species of an Fe^{3+} -reducing, anaerobic methanotroph. Geochemical evidence supporting anaerobic CH_4 oxidation coupled Fe^{3+} -reduction has been reported (Orit Sivan *et al.*, 2011), but the microorganism(s) responsible have yet to be isolated.

Results

Simulation of As transport from the pipeline node using a single pulse of As consistent with the release data reported by HMM/Solution Geosciences report (Shah and Starcher, 2016) does not yield significant As contamination beyond 20 meters from the pipeline in agreement with the findings of the HMM/Solution Geosciences report. This is because of the discrete nature of the As release, the dilution effect and the absorption of the tiny amount of As by HFO in the medium. We also fit the As leach experimental results of the HMM/Solution Geosciences report as a first order reaction rate. This increased the dispersion of the As over the single pulse release, but did not significantly impact the As concentrations beyond 50 meters from the pipeline node. When using a continuous source of CH_4 the simulations indicated that because of the groundwater flow rates and the hydrological parameters the dissolved CH_4 was quickly dispersed in the aquifer (Figure 4).

The simulations also indicate that because of reaction (1) above, transport of As occurred on the time scale of years reaching concentrations that exceed the 5 pbb and even 10 ppb MCL at distances of 200 meters from the pipeline (Figure 5). The main mechanism for this transport was the increase in pH that occurred in the reaction with pH values increasing in some case up to 8.5 to 9. The increase in pH reduced the K_d value of the HFO's for the adsorbed As and released it into the groundwater. Even though the HFO's down gradient from this release absorbs much of this As, As increase is still seen in the wells. The delay in the As increase is due to the combination of the retardation of As due to its adsorption, first order rate dependency upon CH_4 and the CH_4 and pH travel times. In the case of the well-illustrated scenario in Figure 5, which is 200 meters from the pipeline and at a depth of 110 feet, the 5 ppb New Jersey MCL is exceeded in approximately 3 years for a well pumping at 20 gallons/minute. Around the pipeline the HFO's are almost completely removed by reductive dissolution after several years and no further As is released. The As release zone will be displaced away from the pipeline as the focus of microbial Fe^{3+} reduction migrates down gradient. This migration of the redox zone was the same type of phenomenon predicted by Cozzarelli *et al.* (2016). But more importantly the migration of high pH water down gradient releases As into the

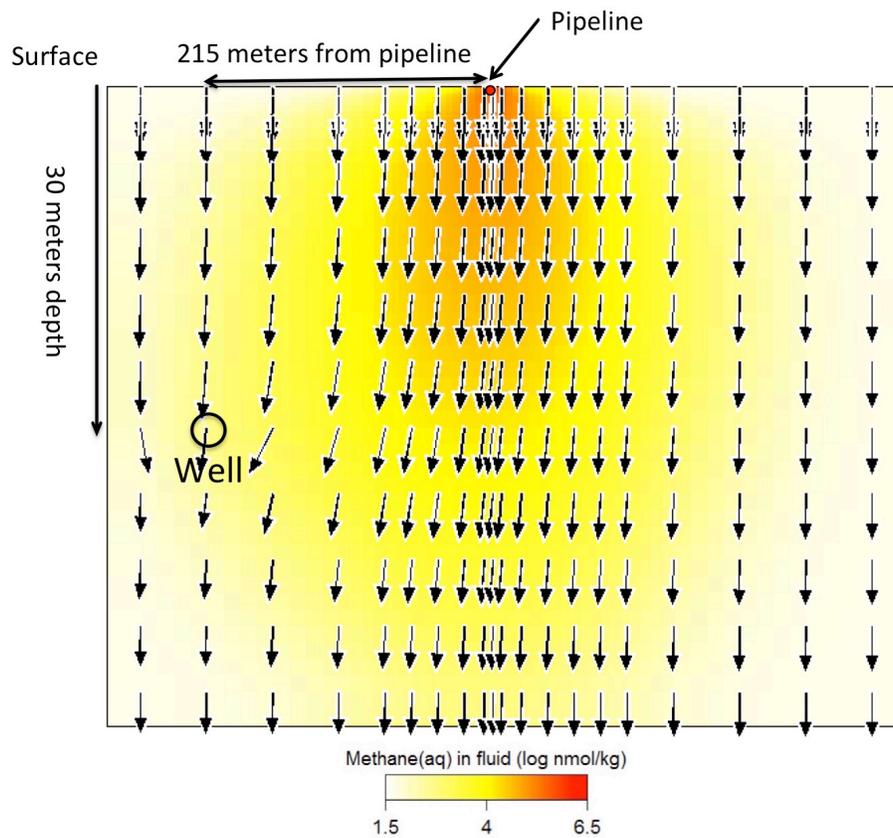


Figure 4. Dissolved CH₄ concentrations for a fluid velocity of 0.14 meters/day, a well pump rate of one gallon/min., and a CH₄ release rate in the pipeline node of 10⁻⁹ mol/kg-s.

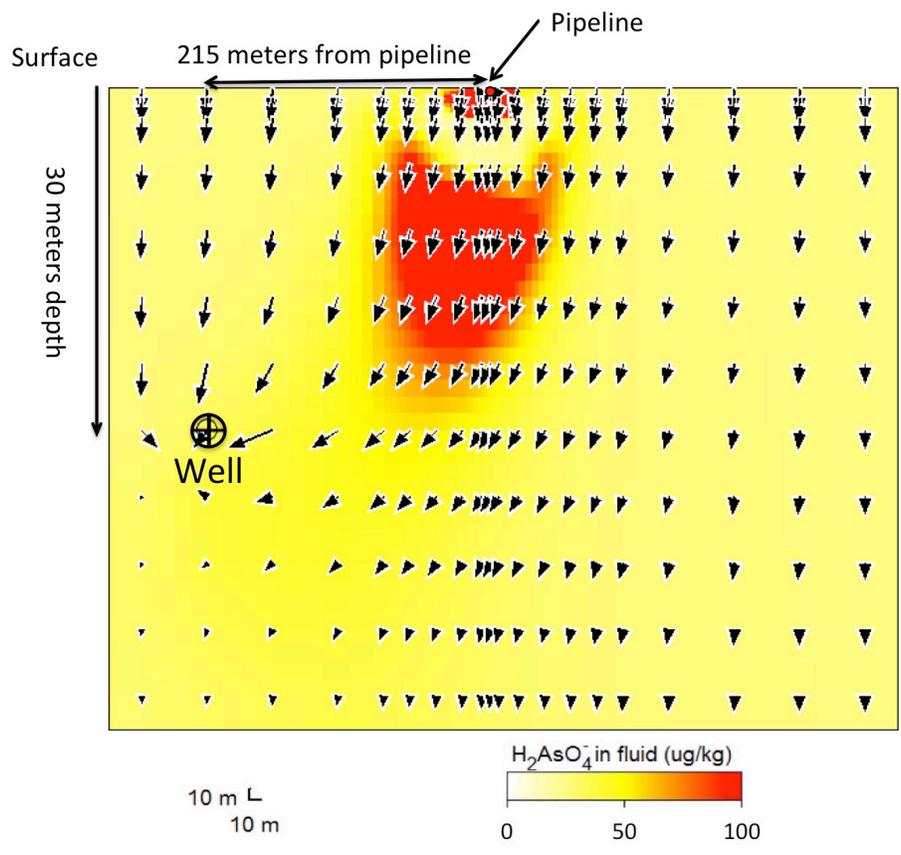


Figure 5. Dissolved $HAsO_4^{2-}$ concentrations for a fluid velocity of 0.14 meters/day, a total adsorbed As concentration of 6 ppm and a well pump rate of 20 gallons/minute. Time = 2 years.

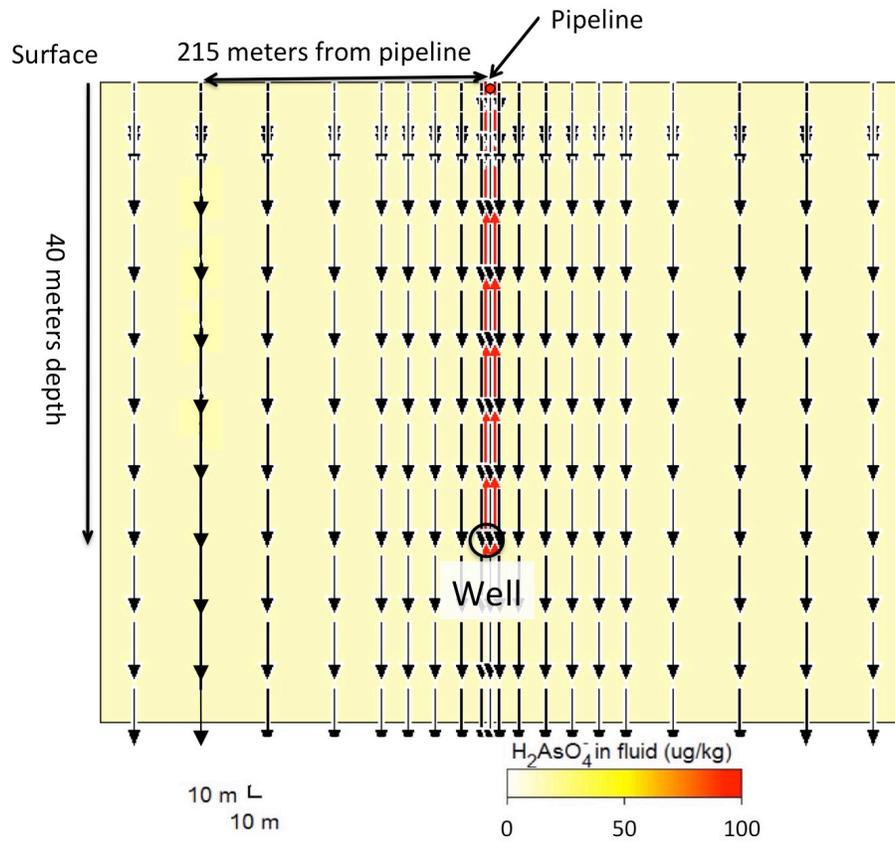


Figure 6. Dissolved $HAsO_4^{2-}$ concentrations for dual porosity with fracture transport. Horizontal transport distance from pipeline is 300 meters. Time = 20 years.

groundwater. Depending upon the position of the well and its pump rate, the CH₄, the high pH, and the As pulse is drawn towards the well. The simulations also indicate the presence of a protracted tail in the cases of wells proximal to the pipeline.

Dual porosity simulations of fracture porosity where only 3% of the aquifer volume is available to advective flow are analogous to situations where the pipeline crosses water a high yield dissolution fracture system. If a water supply well intersects the same fracture then high levels of As will travel hundreds of meters in less than 20 years. This is consistent with the observations of Herman (2010). The travel time will simply depend upon the well pump rate and the transmissivity of the dissolution fracture. If the water supply well does not intersect the same fracture system then its As concentration will not be significantly impacted despite being located within 50 meters of the pipeline.

In dual porosity models where the geometry is treated as 10 meter size blocks formed by intersecting fracture sets, CH₄ travels advectively through the permeable pathways, but only penetrates diffusively into stagnant volumes of the blocks. As a result reaction (1) takes place at a slower rate and over a much more limited aquifer volume. Similarly, pH in the permeable pathway, which will be high due to the microbial Fe³⁺ reduction, penetrates the stagnant volume diffusively. Any As desorbed in the stagnant volumes must also diffuse outward into the permeable paths before being transported to the well. Initial simulations of dual porosity reaction/transport suggest that if the volume fraction of stagnant volumes in the WBZ's are 70% or greater, the As transport will be greatly reduced. The time scale of this effect does depend somewhat on the size of the stagnant zones. Determining these parameters requires performance of cross-borehole tracer tests similar to those carried out by Carleton et al. (1999).

Discussion

Groundwater As contamination - In the simulations above, the time scale for migration As into wells occurred over years for a spatial scale of a couple of hundred meters. Natural gas transmission pipelines crossing Hunterdon and adjacent counties have been present for many decades, perhaps as long as 60 years. The Algonquin Pipeline crosses the Middle Gray and Middle Red WBZ's of the Brunswick Shale on its route through Hunterdon County and lies at the center of a linear trend of high As wells (Fig. 7). The water-supply wells in this area range in age from 1970 to 2012 and were thus installed many decades after the Algonquin pipeline was constructed. The wells range in depth from 100 to 550 feet. Plots of the As concentration of water-supply wells survey by the Raritan Headwaters (MacDonald and Mitchell Thomas, 2016) within 800 meters of the Algonquin pipeline reveal maximum values decreasing with increasing distance from the pipeline as determined through Arc-GIS measurements (Raritan Headwaters pers. comm., 2016; Fig. 7). Some of the wells close to the pipeline, however, have non-detectable As, but because the survey collected water samples from wells with and without As filtration systems we do not know if this is obfuscating spatial trends. Further analyses of the geochemistry of these wells need to be undertaken and combined with 3D fluid flow models to determine whether gas pipelines are creating a long-term source of reductants that are feeding subsurface microbial communities and resulting in the release and migration of As.

The aquifers of the Passaic Formation shale are best characterized as a leaky multi-unit aquifer, or LMA (Michalski, 2010), where cross flows in wells are common. Ayotte et al. (Ayotte *et al.*, 2011) stress the importance of cross flows in spreading As contamination from one aquifer into another. The rural water-supply wells in Hunterdon County are cased to depths that are typically shallower than the 100 to 200 foot depth to which weathering extends (Herman, 2010). This indicates that these wells will have access to the water-table portion of the aquifer (Herman, 2010) and thus they will be prone to contamination from the PennEast pipeline trench. This has not been modeled in our simulations, but points to multiple paths for the entry of As into water-supply wells proximal to the PennEast pipeline.

The modeling shows that As contamination will occur even with conservative estimates of the organic carbon contamination and As abundance. Many other microbial metabolisms are involved in the oxidation of organic carbon that could lead to mobilization of As, but this model emphasizes just one metabolism, Fe^{3+} reduction. This metabolism was only mentioned once in passing in the HMM/Solution Geosciences report (Shah and Starcher, 2016), but not treated with the attention it deserved. Zhu et al. (Zhu *et al.*, 2008) demonstrated that anaerobic sulfate-reducing bacteria stimulate the release of As from arsenopyrite from Lockatong Formation into the groundwater. In this case the HS^- substitutes for As in the arsenopyrite to form pyrite, thus releasing the As. The presence of both Fe^{3+} -reducing and sulfate-reducing bacteria in the soils and aquifer of the Newark Basin would indicate that the metabolic potential for these reactions are present. As such an investigation of the microbial community composition of sites along the proposed PennEast ROW needs to be undertaken.

Surface water As contamination - The proposed pipeline ROW parallels the Delaware River thereby crossing numerous streambeds and wetlands, which in this region are typically receiving discharge from groundwater (gaining streams) (Mumford *et al.*, 2015). These groundwater discharges into gaining streams in the Raritan River watershed have been shown to transport As into the stream water and stream bed sediments and are undoubtedly doing the same in the Delaware River Basin. As a result of the PennEast design, any pollutant transported along the highly porous and permeable pipeline trench will have maximum impact on all the streams that it crosses. The As release problem will be enhanced by the cement-filled bags used in the stream crossing to reduce erosion within the trench (Figure 20 of the FERC DEIS). The interaction of trench water with the cement will increase the trench water pH, leading to release of As from the backfill soil that will then enter the stream. Even for HDD crossings, pollutants upwelling from the borehole into the overlying streams will have maximum impact on the pollutant load of the stream.

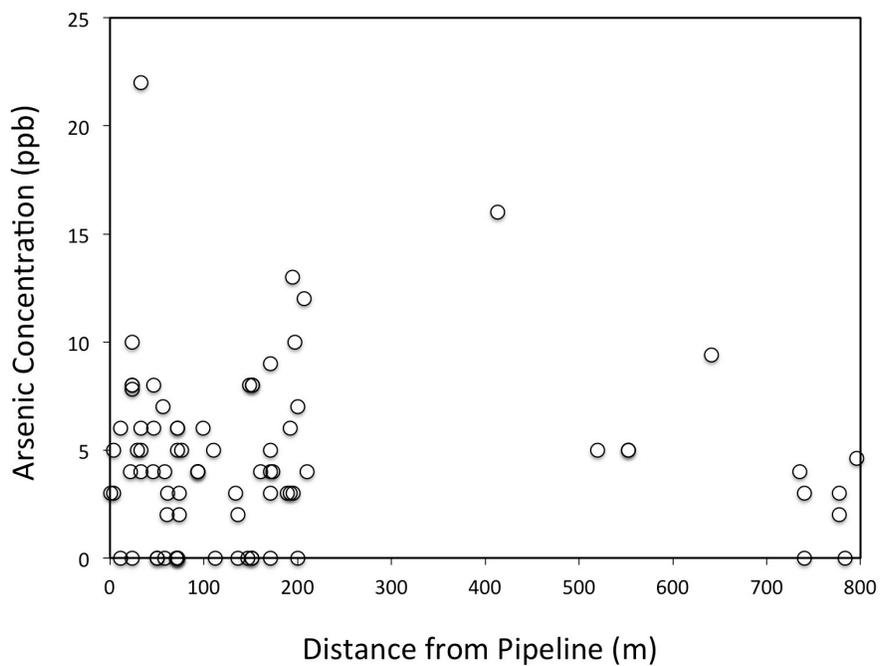
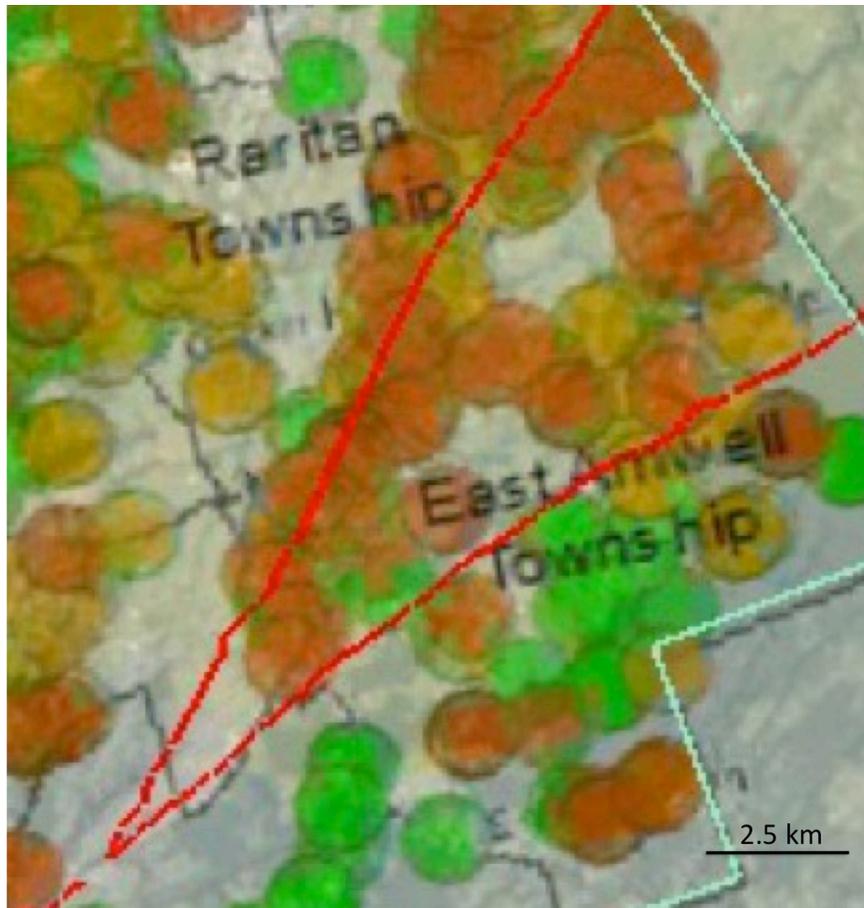


Figure 7. (top) Trace of Algonquin pipeline through East Amwell and Raritan townships. (bottom) Plot of As concentrations from water supply wells versus distance from the Algonquin pipeline determined by ArcGIS (Raritan Headwaters, pers. comm. 2016).

Conclusion

The FERC DEIS states on page 5-3 that "*We are recommending that PennEast conduct post construction testing of potentially affected wells to identify whether arsenic and/or uranium concentrations have increased above safe drinking water levels. In the unlikely event that the construction Project causes a significant impact on a water-supply well, PennEast would provide a treatment system to remove arsenic from the drinking water at individual properties or find an alternative water source.*" FERC does not state the time frame over which testing would occur, nor which water-supply wells would be tested, but only that water-supply wells within 150 feet of the proposed construction space would be tested.

This results of 2D reactive transport modeling of a leaking gas pipeline in the Passaic Formation indicates that the FERC DEIS has seriously underestimated the potential environmental risk to groundwater in Hunterdon County. The model results indicate that CH₄ migration into the pipeline trench and WBZ's will release As into the groundwater, but that because of retardation of the As during transport, this As may not arrive in water supply wells until years after the construction is completed. This report also clearly demonstrates that the mitigation strategy proposed by FERC in its DEIS is grossly inadequate as it does not consider the time or distance scale over which the contamination occurs. Monitoring for As cannot just be restricted to the construction phase, but needs to be extended over years. PennEast has to be prepared to pay for the purchase and the replacements of As filtrations systems over decades.

Acknowledgments

Raritan Headwaters provided Arc-GIS measurements of distances from the Algonquin pipeline to the wells in their database for which we are grateful.

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Abundant Fe, As, and S Bacteria Along the Proposed PennEast ROW and How They Will Mobilize Arsenic and Corrode the PennEast Pipeline

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Summary

Analyses of the microbial communities present along the proposed ROW of the PennEast pipeline have revealed an unusually high proportion of bacteria involved in the reduction of Fe(III), sulfate and in the cycling of As. This means that As release into the groundwater from the construction and operation of the proposed PennEast pipeline is a certainty as the metabolic potential clearly exists in the microbial communities that will be surrounding the pipeline. Furthermore the unusually high proportion of sulfate reducing bacteria, the principal microbial agents for microbial induced corrosion of steel, means that the safety of the pipeline is in jeopardy should any failure of the epoxy coating or cathodic shield occur. Unfortunately the cathodic shield that will be required raises the pH of the groundwater surrounding the pipeline, desorbing As from the iron oxyhydroxide minerals and releasing it into the groundwater.

Introduction

Arsenic (As) is abundant throughout the Stockton, Passaic and Lockatong Formations in the Newark Basin, with reported concentrations in the rock as high as 248 ppm (Serfes et al., 2010) and measured concentrations as high as 359 ppm measured in the weathering horizon (Schick, 2008). As in the rock occurs predominantly as fine-grained arsenopyrite, FeAsS, or arsenopyrite inclusions within pyrite, and or as As anion species adsorbed to ferric oxides and hydroxides (Serfes et al., 2010). Given the New Jersey Surface Water Quality Standard (SWQS) for arsenic is 0.017 ppb (N.J.A.C., 2011), while the NJ drinking water standard is 5 ppb, the release of naturally-occurring As poses a significant risk for local aquifers. Bacterial communities can increase As in groundwater by reducing As from As(V), or arsenate, to its more toxic form As(III), or arsenite (Cullen and Reimer, 1989; Fan et al., 2007), thus causing desorption from ferric iron oxyhydroxides (HFO's) surfaces for most pH's (Serfes et al., 2010). Another major concern is the reductive dissolution of HFO's by Fe(III)-reducing bacteria. Fe-reducing bacteria are commonly thought to play a role in the mobilization of As as a result of its basic metabolic process which converts HFO, essentially rust, into Fe(II), the soluble form of iron, thereby eliminating the mineral phase in the aquifer sediment to which As is absorbed. Still another concern regarding Fe(III)-reducing bacteria is that their metabolic activity raises the pH from neutral to values that exceed the zero point charge (ZPC) of the HFO. Under circum neutral pH the HFO has a positive surface charge that attracts the negatively charged arsenate anion species. But at pH values greater than the ZPC, the surface charge becomes negative and arsenate is no longer strongly attracted to the HFO. The taxonomic identities of Fe(III)-reducing bacteria have been reported extensively in literature and are widely distributed among various Bacterial and Archaeal phyla (i.e. Weber et al., 2006). Additionally, sulfate-reducing bacteria can cause the release of As from the sulfide mineral arsenopyrite, FeAsS, under anoxic

conditions (Zhu et al., 2008). The H₂S generated by their metabolic processes exchanges S for the As in FeAsS to produce pyrite, or fool's gold, FeS₂. The taxonomic distribution of sulfur species-reducing bacteria are more restricted than that of the Fe(III)-reducing bacteria, but are well known. To elucidate the proportion of genera that could contribute to the mobilization of As around the PennEast pipeline, samples of streambed and wetland subsoils at several locations along the proposed PennEast ROW were collected for DNA analysis. They were selected for this analysis because the current PennEast proposal specifies that the subsoil will be used as backfill for the trench, thus placing these soil bacteria in proximity to the proposed pipeline.

Methodology

Multiple soil samples were collected along the PennEast ROW, with a focus on stream and wetland sediments. An auger tool was used to collect subsurface soil samples, and each sample was further partitioned based on perceived changes in soil horizon. The color of the selected sub-soils ranged from grey to red.

Sample Descriptions:

- *Samples 1-4:* These samples were taken at mile marker 96.8 along the pipeline ROW near Wickicheoke Creek. Samples 1-2 were taken from the edge of the creek and contained gray silt, clay, and organics. Samples 3-4 were taken several feet from Wickicheoke Creek amongst tree roots and contained abundant gray silt.
- *Samples 5-6:* These samples were taken on an elevated wetland near mile marker 95.2 along the proposed ROW. The samples were primarily composed of gray clay and contained Fe-stains at depth.
- *Samples 7-10 :* These samples were taken near mile marker 86.3 along the ROW, near Harihokake Creek. These samples contained red silt mixed with coarse grains, which were removed in the lab. Samples were both taken at the water's edge.

DNA Analyses:

In the lab, coarse particulate matter and roots were removed by hand, and the remaining sample was sieved through 80 mesh. These soil samples represent a range of potential environments, including wetlands and stream sediments.

DNA/RNA extractions were performed on a subsampling of the soil samples, following a modified version of the procedure outlined in "Powersoil DNA isolation kit" (MO BIO Laboratories, Inc., 2746 Loker Avenue West, Carlsbad, CA 92010), developed for use with soils containing a high humic acid content. The quality of the DNA was confirmed by gel electrophoresis. Resultant DNA was sent to *Mr DNA* for sequencing. The procedure taken to isolate and identify sequences is described by *Mr DNA*:

"The 16S rRNA gene V4 variable region PCR primers 515/806 (Caporaso et al., 2011) were used in a single-step 30 cycle PCR using the HotStarTaq Plus Master Mix Kit (Qiagen, USA) under the following conditions: 94°C for 3 minutes,

followed by 28 cycles (5 cycle used on PCR products) of 94°C for 30 seconds, 53°C for 40 seconds and 72°C for 1 minute, after which a final elongation step at 72°C for 5 minutes was performed. Sequencing was performed at MR DNA (www.mrdnalab.com, Shallowater, TX, USA) on an Ion Torrent PGM following the manufacturer's guidelines."

Sequence data were processed using a proprietary analysis pipeline (MR DNA, Shallowater, TX, USA) which proceeded as follows: 1) the sequences were depleted of barcodes and primers, 2) the sequences with <150 base pairs were removed, 3) the sequences with ambiguous base pair identities and with homopolymer runs exceeding 6 base pairs (e.g. [AAAAAAA...](#)) were also removed. Sequences were then denoised, were checked for chimeras and the chimeras removed. Operational taxonomic units (OTUs) were defined by clustering at 3% divergence (97% similarity). Final OTUs were taxonomically classified using a nucleotide BLAST (Basic Local Alignment Search Tool) against the curated 16S rRNA and 18S rRNA sequence databases at GreenGenes, RDPII and NCBI (www.ncbi.nlm.nih.gov, DeSantis et al., 2006, <http://rdp.cme.msu.edu>).

Results from *Mr. DNA* included relative abundances of each Operational Taxonomic Unit (OTU) derived from GreenGenes. Results were filtered to include bacteria known to reduce Fe(III) (i.e. Weber et al., 2006; Lonergan et al., 1996; Jones et al., 1983; Knoblauch et al., 1999; Mact et al., 2000; Slobodkina et al., 2012; Anderson and Cook, 2004), those known to either reduce or oxidize arsenic (i.e. Cullen and Reimer, 1989; Fan et al., 2007) and those known to reduce sulfur species, including sulfate, sulfite, thiosulfate, and sulfur to produce H₂S (i.e. Amann et al., 1992; Castro et al., 2000; Muyzer and Stams, 2008). The microbial communities were analyzed for each sampling location at both the phylum and genus levels. Abundances less than 0.5% were rounded down to zero, and the residual was reported as "Other". The percent abundance of each genus per sample is shown in Appendix A. A literature review was conducted to determine the proportion of total genera with the capacity to mobilize As, either through Fe(III)-reduction or As oxidation or reduction, or sulfate reduction and these percentages are also included in Appendix A. This number likely serves as a lower limit, since 860 genera were recorded in the microbial assay and some may have been overlooked in the literature review.

Results and Discussion

The total percentage of As-mobilizing genera was compared to the total As concentration of the sub-soil sample (as measured on an ICP-MS) and the underlying bedrock formation (Stockton, "S"; Passaic, "P"; and Lockatong, "L") for each sample site (Table 1).

At the phylum level, results were dominated by Proteobacteria (36-51%), especially Deltaproteobacteria (16-29%) and Betaproteobacteria (9-12%), as well as Bacteroidetes (3-22%). Samples from more arid soil environments (3-6) tended to have a lower percentage abundance of Bacteroidetes (Figure 1). Samples 5-6 from the elevated wetland had the most distinctive microbial communities, with a notably higher percentage of Verrucomicrobia (18% compared to 3-8%). This occurrence is significant given the recent discovery of aerobic methanotrophs, CH₄ oxidizing bacteria, in that phylum (Dunfield et al., 2007).

Table 1: Bedrock, As-abundance, and Percentage of bacterial genera known to mobilize As

	1	2	3	4	5	6	7	8	9	10
Underlying Formation	S	S	S	S	L	L	P	P	P	P
As (ppm)	3.30	3.30	0.70	0.70	4.20	4.20	1.80	1.80	2.50	2.50
%Fe, S, As bacteria	25.02	24.85	23.95	27.17	18.14	18.10	25.55	24.10	20.19	19.24

At the phylum level, the soil bacterial communities appear fairly typical, but at the genus level, these communities were quite unusual in the abundance of anaerobic bacteria involved in metal and sulfate reduction (Figure 2). *Geobacter* (4-13%), *Anaeromyxobacter* (1-3%), and *Clostridium* (1-3%) were the dominant genera of the total genera known to mobilize As (11-19% of total reported genera). *Geobacter* is the quintessential Fe(III)-reducing bacterium (Lovley, 1991) that is widespread in aquifers in mainly continental settings and is capable of reductively dissolving all Fe(III) mineral phases including hematite. The 16S rRNA data indicate that several genuses of *Geobacter* are present, including *Geopsychrobacter* (grows at cold temperatures) and *Geothermobacter* (grows at high temperatures). These data suggest that Fe(III) reduction activity will take place even at the high temperatures proximal to the pipeline and at cold temperatures during the winter time. Again, samples 5-6 had a notably different microbial community, with much lower percentages of the Fe, S and As-reducing *Clostridium* compared to other samples, as well as a smaller proportion of As-mobilizing genera overall. This same location had elevated percentages of the sulfate-reducing *Desulfovira* (~2%) compared to other locations.

In a study of an As-rich sulfidic hot spring, Jiang et al., (2016) concluded that the total As, temperature, sulfide, and dissolved oxygen (DO) were all important factors controlling the variation in the microbial community structures of both water and sediment samples from the spring channel. Extensive sequencing surveys are underway to create a global database of soil metagenomes, not just surveys of the 16S rRNA and 18S rRNA genes, in order to understand the microbial functional potential of the soil microbiome and to correlate the microbial community composition with the geochemical properties of the soil. The 16S rRNA bacterial community structure of these soil samples exhibit a surprisingly large proportion of bacteria involved in Fe, S and As cycling. This probably reflects to a large extent the Fe, As and S content of the underlying bedrock.

Furthermore, the high relative abundance of sulfate-reducing bacteria (SRB) may reflect the presence of secondary gypsum in the Passaic Formation shale that formed in the evaporitic lake environment during the Triassic. This was an unanticipated discovery and has great significance for the safety of the PennEast pipeline, as SRB are the principal microbial agents responsible for microbial induced corrosion, MIC, of steel (Baker, 2008; Enning and Garrelfs, 2014). Such a high abundance of SRB means that any failure of the epoxy coatings or the cathodic shield (Lilly et al., 2007) will expose the gas pipeline to external MIC from the outside in

(see Figure 3). Unfortunately the cathodic shield also raises the pH of the groundwater surrounding the pipeline to 9-13 (Norsworthy, 2009), and though this may somewhat reduce SRB activity, it will desorb the As from the HFO. Many other bacteria are adapted to high pH, such as the Fe(III)-reducing *Geoalkalibacter subterraneus* (Greene et al., 2009). Cathodic shields also produce H₂ from the groundwater. The genus level community structure contains bacteria from all metabolic guilds that utilize H₂ as an energy source.

The high abundance of Fe(III)-reducing and As cycling bacteria undoubtedly reflect the high Fe(III) and As concentrations of the Passaic and Lockatong Formation shale. Other than this variation in the soil organic carbon content, water content and DO will affect the microbial community structure. For example, samples 5-6 were taken from the driest environment of those analyzed, and they contained a smaller percentage of *Clostridium*, which is an anaerobic species. In soil samples where the organic carbon content is high and the water content is high, the pore water will have low DO due to the action of aerobic bacteria, permitting the obligate anaerobic *Clostridium* to be active and grow. It is unlikely that the subsoil samples analyzed in this study were impacted by agricultural activity. Subsoil from the farmed lots should also be analyzed.

Therefore, a more extensive survey of such hydrological and geochemical variables plus soil nutrient analyses, microbial abundance, community composition and activity measurements along the PennEast ROW would lead to a better qualitative understanding of how microbial communities will be impacted by altered near-pipeline conditions, and the impact on As mobilization in the trench backfill sediment could then be inferred.

Conclusion

Analyses of the microbial communities present along the proposed ROW of the PennEast pipeline have revealed an unusually high proportion of bacteria involved in the reduction of Fe(III), sulfate and in the cycling of As. This means that As release into the groundwater from the construction and operation of the proposed PennEast pipeline is a certainty as the metabolic potential clearly exists in the microbial communities that will be surrounding the pipeline. Furthermore the unusually high proportion of sulfate reducing bacteria, the principal microbial agents for microbial induced corrosion of steel, means that the safety of the pipeline is in jeopardy should any failure of the epoxy coating or cathodic shield occur. Unfortunately the cathodic shield that will be required raises the pH of the groundwater surrounding the pipeline, desorbing As from the iron oxyhydroxide minerals and releasing it into the groundwater.

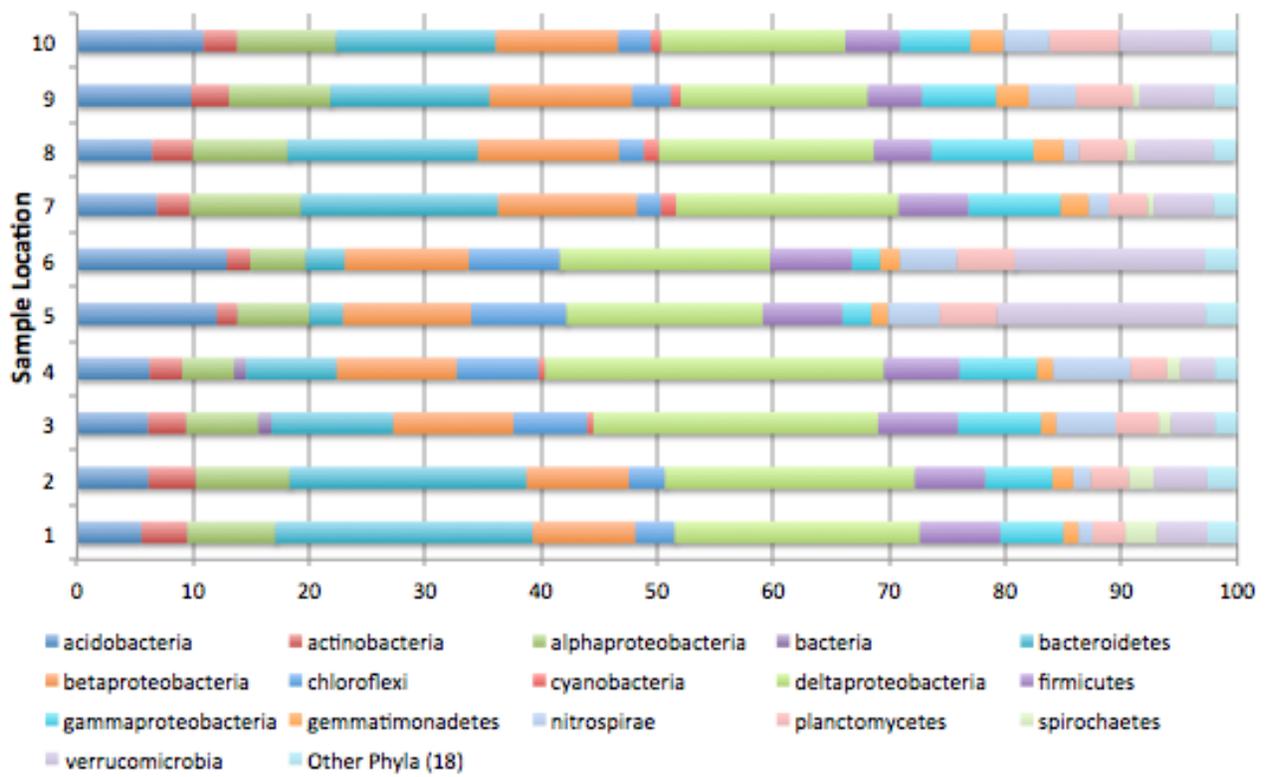


Figure 1: Microbial community structure of water and sediment samples along the PennEast ROW at the phylum level, for abundances greater than 0.5%

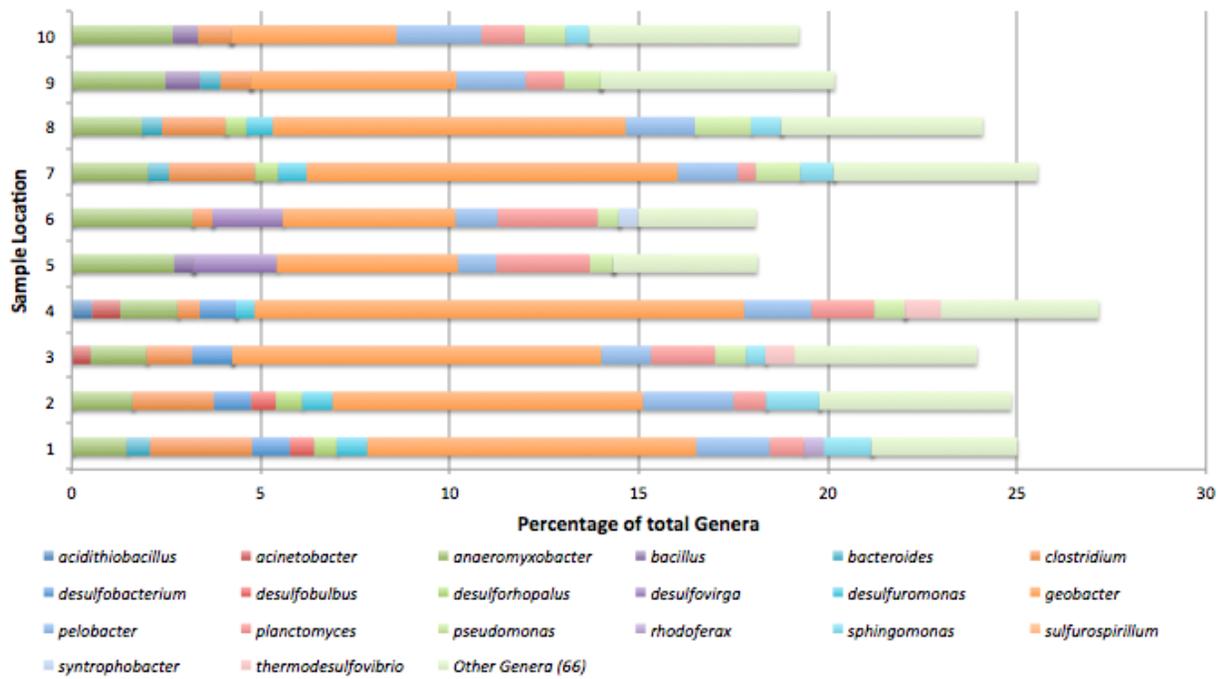


Figure 2: Percentage of microbial community that could act to mobilize As at the genus level, shown for abundances greater than 0.5%

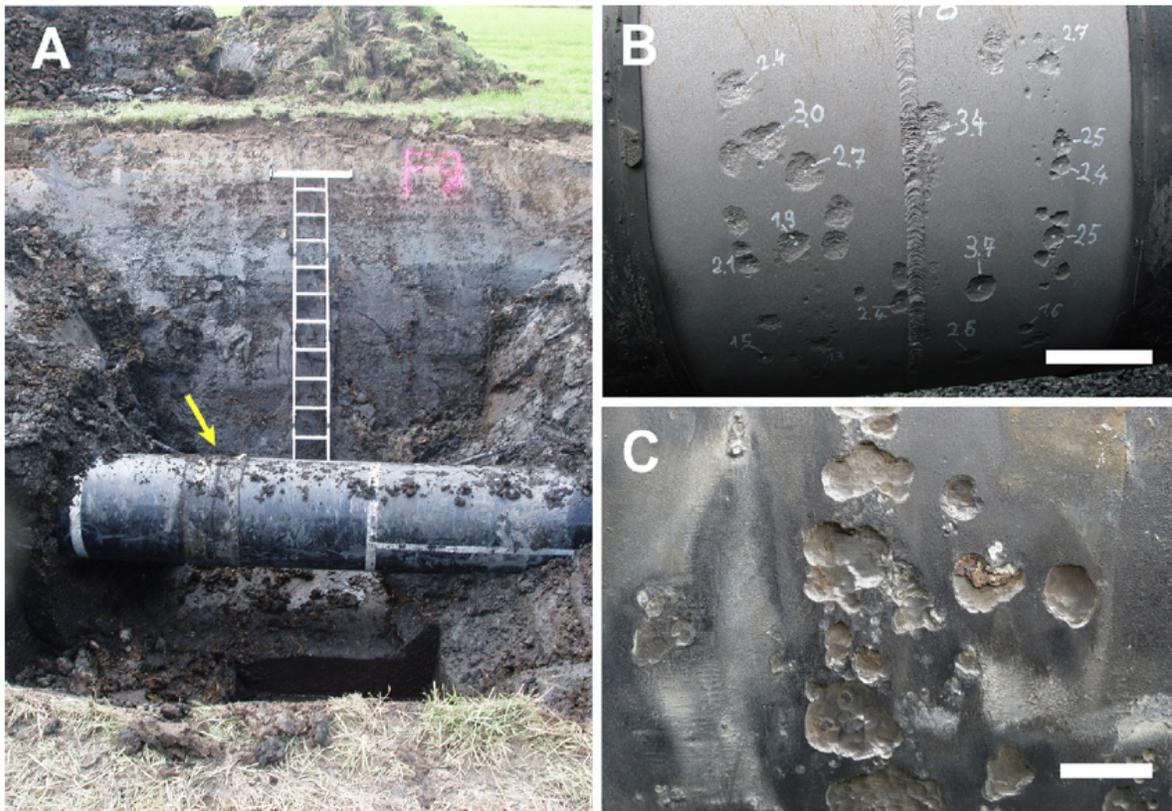


Figure 3. From Figure 1 of Enning and Garrelfs (2014). External corrosion on buried gas transmission pipeline in bog soil of Germany. (A) Trench with coated carbon steel gas pipeline in water-logged, anoxic soil. External corrosion has occurred under disbonded asphalt coating at welding sites (arrow). (B) Welding site with corrosion pits. Disbonded asphalt coating and corrosion products (FeS/FeCO_3) were removed. Numbers indicate pit depth in millimeters. Scale Bar=20 cm. (C) Higher magnification of corrosion pits from a different site at the same pipeline. Scale Bar=2 cm.

Appendix A

Fe-reducing (“R”) and As-reducing (“R” and oxidizing “O”) bacteria, Sulfur species-reducing (“R”) and relative abundances along the PennEast ROW

	F e	As	S	1	2	3	4	5	6	7	8	9	10
achromobacter		R		0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00
acidithiobacillus	R			0.02	0.04	0.49	0.54	0.09	0.05	0.01	0.01	0.06	0.06
acinetobacter		R		0.13	0.18	0.51	0.75	0.42	0.40	0.12	0.09	0.38	0.10
aeromonas	R	R		0.00	0.01	0.02	0.02	0.01	0.00	0.12	0.13	0.05	0.06
agrobacterium	R	R		0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.02	0.01	0.02
alicyclobacillus	R			0.01	0.03	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.02
alkaliphilus		R		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
alteromonas	R			0.04	0.06	0.13	0.08	0.06	0.04	0.08	0.10	0.26	0.33
anabaena		R		0.03	0.03	0.01	0.00	0.02	0.01	0.02	0.02	0.07	0.03
anaeromyxobacter	R			1.45	1.61	1.47	1.51	2.71	3.20	2.02	1.86	2.48	2.68
bacillus	R	R	R	0.11	0.14	0.33	0.15	0.50	0.23	0.36	0.24	0.92	0.67
bacteroides	R			0.62	0.48	0.30	0.29	0.13	0.09	0.55	0.53	0.54	0.38
bdellovibrio			R	0.10	0.09	0.17	0.15	0.04	0.07	0.31	0.21	0.18	0.19
candidatus desulfamplus	R			0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00
candidatus desulforudis			R	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
clostridium	R	R	R	2.70	2.15	1.21	0.59	0.42	0.52	2.28	1.69	0.79	0.87
deferrisoma	R			0.06	0.05	0.02	0.02	0.01	0.00	0.04	0.03	0.07	0.05
deinococcus			R	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
desulfacinum			R	0.01	0.01	0.02	0.05	0.04	0.07	0.01	0.02	0.03	0.02
desulfatibacillum			R	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.02	0.02
desulfatiferula			R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
desulfatirhabdium			R	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
desulfitobacterium	R			0.23	0.30	0.12	0.10	0.19	0.18	0.15	0.09	0.17	0.24
desulfoarculus			R	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
desulfobacca			R	0.01	0.03	0.12	0.12	0.07	0.07	0.01	0.03	0.04	0.04
desulfobacter	R			0.03	0.03	0.09	0.04	0.03	0.01	0.01	0.02	0.05	0.05
desulfobacterium	R	R		1.00	0.99	1.06	0.95	0.10	0.15	0.31	0.37	0.32	0.18
desulfobacula			R	0.08	0.09	0.03	0.01	0.00	0.00	0.07	0.04	0.02	0.01
desulfobulbus	R			0.65	0.65	0.30	0.26	0.02	0.03	0.26	0.26	0.28	0.23
desulfocaldus			R	0.04	0.01	0.00	0.00	0.02	0.03	0.03	0.01	0.01	0.02
desulfocapsa			R	0.20	0.29	0.12	0.14	0.01	0.00	0.11	0.13	0.11	0.08
desulfococcus			R	0.11	0.10	0.21	0.26	0.02	0.03	0.07	0.12	0.12	0.06

desulfofaba			R	0.04	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
desulfofrigus	R			0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.06	0.05
desulfofustis			R	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.03	0.04
desulfoglaeba			R	0.01	0.02	0.04	0.03	0.00	0.00	0.03	0.04	0.03	0.01
desulfomicrobium	R			0.10	0.09	0.02	0.02	0.00	0.00	0.13	0.16	0.01	0.03
desulfomonile			R	0.27	0.24	0.26	0.26	0.31	0.38	0.07	0.09	0.19	0.29
desulfonatronospira			R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
desulfonatronum			R	0.12	0.06	0.03	0.04	0.00	0.00	0.04	0.05	0.04	0.03
desulfonema			R	0.03	0.04	0.07	0.03	0.00	0.00	0.01	0.01	0.02	0.06
desulfonispota			R	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.00	0.00
desulfopila			R	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
desulforegula			R	0.11	0.10	0.07	0.07	0.03	0.05	0.09	0.08	0.06	0.09
desulforhabdus			R	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
desulforhopalus			R	0.59	0.70	0.13	0.13	0.00	0.00	0.61	0.55	0.26	0.13
desulfosarcina			R	0.11	0.11	0.03	0.02	0.01	0.02	0.05	0.03	0.09	0.06
desulfosoma			R	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
desulfosporosinus	R			0.12	0.03	0.03	0.01	0.03	0.02	0.09	0.06	0.03	0.03
desulfotalea	R			0.04	0.04	0.03	0.06	0.00	0.00	0.03	0.06	0.05	0.10
desulfotomaculum	R			0.06	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.01	0.01
desulfovibrio	R			0.22	0.23	0.17	0.26	0.45	0.43	0.22	0.17	0.17	0.15
desulfovirga			R	0.07	0.14	0.04	0.07	2.21	1.86	0.13	0.27	0.41	0.26
desulfovirgula			R	0.00	0.00	0.09	0.09	0.02	0.03	0.00	0.00	0.00	0.00
desulfurivibrio			R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
desulfuromonas	R			0.81	0.81	0.32	0.50	0.06	0.08	0.75	0.69	0.28	0.21
desulfuromusa	R			0.02	0.02	0.03	0.07	0.00	0.00	0.03	0.01	0.03	0.02
enterobacter	R		R	0.01	0.01	0.01	0.00	0.04	0.00	0.23	0.18	0.00	0.01
escherichia	R		R	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
exiguobacterium		R		0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
ferribacterium	R			0.06	0.07	0.05	0.08	0.00	0.01	0.13	0.16	0.22	0.12
geoalkalibacter	R			0.03	0.05	0.05	0.07	0.04	0.01	0.06	0.04	0.04	0.10
geobacter	R			8.70	8.21	9.77	12.95	4.79	4.58	9.82	9.34	5.44	4.38
geopsychrobacter	R			0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
geothermobacter	R			0.06	0.11	0.02	0.02	0.10	0.12	0.14	0.13	0.16	0.21
geothrix				0.23	0.17	0.06	0.08	0.01	0.01	0.25	0.21	0.16	0.13
herpetosiphon			R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
hydrogenophaga		O		0.02	0.01	0.02	0.00	0.00	0.01	0.11	0.11	0.05	0.00
myxococcus			R	0.02	0.03	0.01	0.02	0.00	0.00	0.00	0.00	0.02	0.03
paludibacter			R	0.06	0.05	0.03	0.01	0.18	0.18	0.11	0.07	0.12	0.06
pelobacter	R		R	1.94	2.39	1.31	1.78	1.01	1.11	1.58	1.83	1.83	2.24
planctomyces			R	0.91	0.86	1.69	1.66	2.48	2.65	0.48	0.45	1.02	1.14
pseudomonas	R	O		0.30	0.47	0.82	0.81	0.61	0.55	1.18	1.48	0.96	1.09

rhodobacter	R			0.09	0.07	0.06	0.05	0.00	0.00	0.32	0.22	0.06	0.07
rhodoferax	R			0.52	0.38	0.22	0.24	0.03	0.03	0.46	0.37	0.21	0.21
shewanella	R			0.00	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.02
sinorhizobium		O		0.03	0.03	0.00	0.00	0.03	0.01	0.02	0.02	0.01	0.02
sphingomonas		O		1.26	1.41	0.51	0.26	0.01	0.03	0.88	0.80	0.40	0.61
sulfurospirillum	R	R		0.03	0.02	0.02	0.02	0.02	0.01	0.06	0.04	0.01	0.01
syntrophobacter			R	0.07	0.07	0.16	0.21	0.47	0.52	0.13	0.06	0.31	0.27
thermoanaerobacter			R	0.03	0.02	0.04	0.04	0.06	0.03	0.02	0.04	0.07	0.05
thermodesulfobacterium	R		R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
thermodesulfovibrio			R	0.08	0.09	0.77	0.95	0.11	0.12	0.08	0.05	0.15	0.19
thermovenabulum	R			0.04	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.03
thermus	R	O		0.09	0.09	0.06	0.07	0.04	0.04	0.11	0.10	0.12	0.13
vibrio	R			0.00	0.00	0.05	0.05	0.00	0.00	0.01	0.00	0.00	0.00
Percentage of total				25.02	24.85	23.95	27.17	18.14	18.10	25.55	24.10	20.19	19.24

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Exhibit C

Arsenic release into stream waters from the PennEast Pipeline

Background

The New Jersey Surface Water Quality Standard (SWQS) for arsenic is 0.017 ppb (N.J.A.C., 2011). Trenching activity during the construction phase of the PennEast pipeline across streams and wetlands feeding streams could potentially release arsenic into the surface water, exceeding the SWQS and requiring implementation of a Total Maximum Daily Load (TMDL). No information, however, is available on the arsenic concentrations of soils and sediments along the streams entering the Delaware River in Hunterdon County and no data was presented in the proposal submitted by PennEast Pipeline, LLC.

Methodology

Samples of stream and wetland sediments and soils, therefore, were collected at multiple locations along the ROW of the proposed PennEast pipeline. A 30 cm long metal auger tool was used to collect soil samples from beneath the surface vegetation and the organic-rich A horizon and from at least 3 sites for each location sampled and from multiple depths down to 30 cm. These samples were sieved through 80 mesh to remove coarse, detrital grains and roots were physically removed before sending the samples off for trace/minor/major metal analyses by ICP-MS.

Results

The results from 44 field samples revealed a wide range of arsenic concentrations up to ~8 ppm and, in some cases, revealed increasing arsenic concentrations with depth down to 30 cm. Serfes et al. (2010) reported that this phenomenon of arsenic concentrations increasing with depth down to the bedrock was discovered by Schick (2008)¹ who found arsenic concentrations as high as 359 ppm at the base of soils in this area. In several cases, the high arsenic concentrations may correlate with the fact that the bedrock is an arsenic-rich gray bed in the Passaic Formation. The average arsenic concentration of soil taken from the sites overlying the Passaic gray beds was 5.3 ppm (n = 9), which, if mobilized, would cause exceedance of both the SWQS and the NJ drinking water standard of 5 ppb.

Trace/minor/major metals were also analyzed on the ICP-MS and averaged according to underlying bedrock, as arsenic may become mobilized as a result of interaction with metals encountered in the sub-trench environment (Table 1). For example, competing ions such as phosphate have been shown to release adsorbed arsenic into groundwater (Serfes et al, 2010). Preliminary results also show a correlation between percent iron and arsenic concentration, which may be due to the presence of hydrous ferric oxides (HFOs) or arsenopyrite. However, more extensive analyses are needed to understand the connections that may exist between these variables.

Discussion

Overall, a more thorough arsenic survey at the stream crossings and from greater depths in the soil/wetland zones needs to be performed along the proposed PennEast ROW in order to provide an assessment of the environmental risk posed by the removal of surface vegetation and the topsoil in and adjacent to the stream crossings during the construction phase. The potential for release of organic carbon (which stimulates the growth of bacteria shown to mobilize arsenic) as well as direct mobilization of arsenic exists with such disturbance (Mumford et al., 2014). This has yet to be studied along the proposed pipeline ROW.

The long-term release of arsenic into the overlying streambed from the backfill trench sediment, which will be composed of the same arsenic-rich soil, also needs to be evaluated. The arsenic release mechanism will not only include erosion of the backfill but also groundwater migration through the trench backfill from both sides of the stream and upwelling into the overlying stream sediments. This process is likely to persist throughout the lifetime of the pipeline. Thus, these measurements are essential in order to determine the arsenic load that will be released into the stream water both during and following construction. It is important to note that the concentrations of arsenic in the soils are present in parts per million (ppm). The existing water standards are 5 parts per billion (ppb) for drinking water—in many cases, that is groundwater—and for surface water, the SWQS is 0.017 ppb. Therefore, the concentrations of arsenic in the stream channel soils are more than 1,000 times greater than the SWQS. If only 0.0004% to 0.0006% of the arsenic were released from the soils into the stream water it would be in exceedance of the SWQS. The percentage release of arsenic from the sediment cores during the leaching experiments reported in the HMM/Solution Geosciences Report on Arsenic (Shah and Starcher, 2016) are well in excess of these values, yet they failed to mention this in their report .

Conclusion

In the case of stream waters, given the elevated arsenic concentrations that we have found, the SWQS will likely be exceeded should arsenic be released from soils, and a TMDL would then need to be determined for any stream where the SWQS or the background level of arsenic is exceeded. Without undertaking such studies the DEIS cannot provide an accurate assessment of the environmental risk posed by the PennEast Pipeline to the stream waters. As a result of this incomplete analysis FERC cannot justifiably assess whether this risk is serious enough that they require the PennEast Pipeline LLC to select an alternative ROW.

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Table 1: Trace metal breakdown of samples, averaged by formation

Formation	As average (ppm)	Fe average (%)	Co average (ppm)	Cu average (ppm)	Hg average (ppm)	Mn average (ppm)	P average (%)	Pb average (ppm)
Stockton (n = 8)	2.8	1.8	10.7	23.7	0.038	362	0.065	24
Lockatong (n = 4)	3.1	1.8	6.7	17.6	0.035	281	0.060	21
Passaic (n = 23)	3.1	2.0	8.0	23.7	0.030	457	0.060	17
Passaic gray beds (n = 9)	5.3	2.3	8.8	31.9	0.039	370	0.056	21

Exhibit D

Comment on Potential Boron Contamination of Lambertville Drinking Water

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A study by the U.S. Geological Survey has found elevated boron concentrations in well water near the New Hope, Pennsylvania area immediately across the river from Lambertville, New Jersey (Senior and Sloto, 2006). The boron concentrations in 10 wells sampled between October of 2004 to April of 2005 ranged from 6 to 3,170 ppb. The highest concentrations, 2,030 to 3,170 ppb, were found in wells located in the diabase of Jericho Mountain. Of the 10 wells analyzed 4 exceeded the lifetime Health Advisory (HA) of 600 ppb recommended by the U.S. EPA and this high frequency of exceedance is greater than that observed for the Newark Basin at large.

The source of the boron in the ground water is likely due to the mineral datolite, which is found in the metamorphosed sediment, or hornfels, adjacent to the intrusive diabase (Van Houten, 1971). Boron stable isotopic analyses have confirmed that the boron in the groundwater near New Hope originated from the hornfels or veins in the diabase. The concentration of boron in datolite is 4,000 times that of mafic magma and likely originated from the clay-rich sediments deposited in the Triassic lake of the Newark Group (Senior and Sloto, 2006). Even though boron concentrations are correlated with arsenic concentrations in the sediments of the Newark Group, boron has a single valence state and thus is not influenced by the same redox processes that affect the mobilization of arsenic. The principal aqueous species of boron is boric acid and is typically mobile.

The proposed PennEast ROW crosses the hornfels facies of the Passaic shale and the diabase of Bald Pate Mountain in the immediate vicinity of the drinking water supply for Lambertville. Drilling and blasting will be required because of the thin soil cover resulting in an increase of fracture porosity and ground water flow along the back-filled trench and will likely increase the dissolution of boron-bearing mineral phases in both rock types.

The application filed by PennEast with FERC fails to mention the possible effects of boron contamination. FERC also fails to mention this in their DEIS statement despite the fact that the PennEast document cites the Senior and Sloto (2006) study at the top of page 6-39 of Resource Report 6. Field studies need to be undertaken to determine whether the proximity of the proposed pipeline to the water supply of Lambertville risks exposure of the citizens of Lambertville to elevated boron concentrations exceeding the U.S. EPA. These studies need to begin with measurements of the boron concentrations in private wells in the immediate vicinity of the proposed ROW where it crosses outside of Lambertville.

We also point out that spring sources with boron concentrations up to 741 ppb have been identified in the Lokatong headwaters by NJ Water Supply Authority. Since PennEast

has proposed horizontal directional drilling (HDD) in the Lockatong Creek and further studies of the boron load on the Lockatong Creek and potential sources is warranted before approving of the HDD plan.

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