WHITE PAPER:

PIPELINES A SIGNIFICANT SOURCE OF HARM

Recent technological developments, such as high-volume multistage slick-water horizontal hydraulic fracturing, have created a new industry focused on the extraction of natural gas from shale.[1] Currently there is a moratorium on shale gas extraction within the boundaries of the Delaware River Watershed, but if this moratorium (in place under the authority of the Delaware River Basin Commission – DRBC) were lifted, and the ban on fracking in New York were to be reversed, it is estimated that a total of 18,000 to 64,000 wells could be drilled in the Delaware River.[2] But outside of the boundaries of the watershed, particularly in central and western Pennsylvania, shale gas extraction using drilling and fracking technology is proliferating at a rapid pace. Not only are the well pads and methods used to extract shale gas dangerous to human health and the environment, but the development of the supporting infrastructure – in particular the pipeline delivery systems – necessary to move this gas to market is having significant impacts on the environment and communities, including within the boundaries of the Delaware River watershed.

Pipeline delivery systems transport gas from wellhead to the market.[3] The Delaware River Basin is experiencing a surge of infrastructure development designed to move gas from the shale fields of Pennsylvania where drilling is happening to markets in Northeastern and Mid-Atlantic States. A typical pipeline delivery system can be found in figure 1[4].

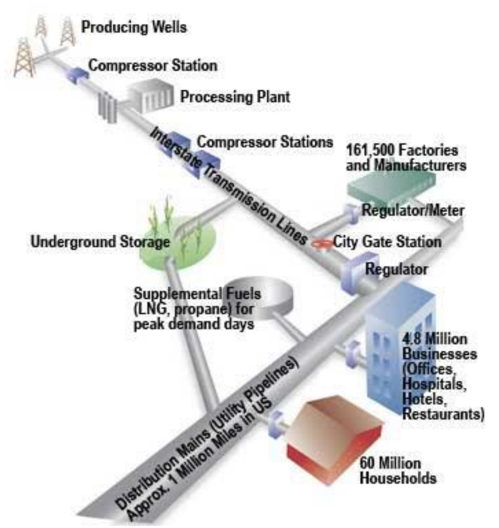

Figure 1: Typical pipeline delivery system.

Based on estimates of gas which is proved, probable and recoverable, experts believe there is only 11 to 21 years of U.S. energy which can be supported by all U.S. natural gas supply.[5] This factual scenario begs the question, whether incurring all of the harms of shale gas extraction and making the huge financial investment in pipeline infrastructure is the best use of limited resources? Aren't we better served investing in the infrastructure that will avoid the ecological harms of shale gas and instead support the perpetual energy that sustainable energy options such as wind, solar and geothermal can provide?

[1] U.S. Department of Energy, Modern Shale Gas Development In The United States: A Primer, 8 (April 2009).
[2] Estimate was developed using the planning assumptions put forth by DRBC's Expert Report prepared in the Matter of Delaware River Basin Commission Consolidated Adjudicatory Hearing on Natural Gas Exploratory Wells, by Patrick M. O'Dell, P.E., "Potential for Development of Natural Gas Exploratory Wells to Adversely Affect Water Resources of the Delaware River Basin", National Park Service Geologic Resources Division, November 23, 2010, pp. 7-8.
[3] Nels Johnson, et al., Natural Gas Pipelines, The Nature Conservancy, 1 (December 2011).
[4] Image from, http://www.duke-energy.com/pdfs/AGA_pipeline_insert.pdf.)
[5] "What the Frack? Is there really 100 years' worth of natural gas beneath the United States?" by Chris Nelder. Dec 29, 2011. See also "Top Three Reasons Cheap Natural Gas Won't Kill Renewable Energy", By Stephen Lacey, Feb 21, 2012.

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I. The Parts of a Pipeline

The vast majority of natural gas gets to markets through pipelines. Every new natural gas well pad requires at least one gathering pipeline. A gathering line is typically a 6 to 24 inch steel pipe that can be miles long and carries the raw gas at approximately 350 psi. A study in Bradford County Pennsylvania has determined that each well drilled requires at least 1.6 miles of new gathering pipeline to be constructed.[6] Many of the new gathering lines currently under construction, such as a gathering line system built by Chesapeake Energy in central Pennsylvania, are as large as the interstate pipelines and operate at similarly high pressures.[7] This recent increase in the size and scope of gathering lines is becoming more common throughout Pennsylvania. Ultimately, these gathering lines are connected to larger capacity high pressure transmission pipelines that are capable of moving the gas hundreds of miles to their points of delivery.[8] Smaller distribution lines then take the gas from the transmission line to each individual home/end user. A typical well pad and gathering line can be seen in figure 2.[9]

Figure 2: Picture of a well-pad and gathering line located in Amwel Township, Pennsylvania

In addition to the pipelines themselves, compressor stations need to be constructed every 30 to 60 miles in order to boost pressure in the line as it is lost to friction. These compressor stations are usually comprised of multiple engines, generating thousands of horsepower by either burning off some of the natural gas that comes through the pipeline or through separate fuel supplies. Other appurtenant facilities, such as valve shut-off joints and pig launchers (delivery points for pipeline integrity monitoring devices), also need to be constructed and integrated into the system.

One simple way to look at a pipeline delivery system is to picture it as a large sprawling tree: the roots (gathering lines), the trunk (transmission lines), and the branches (distribution lines). As the development of the Marcellus Shale, Utica Shale and Upper Devonian Shale intensifies, the network of pipelines, will significantly grow.

II. Construction Methods

There are three broad categories of construction methods for pipelines crossing water-bodies: “wet” ditch crossing, “dry” ditch crossing or horizontal directional drilling that passes below the waterbody.[10] A “wet” ditch crossing encompasses any dredging construction activity that takes place while the water body continues to flow. “Dry” ditch crossings are aimed at transferring stream flow around the work area and encompass two primary techniques: dam and pump or flume. Horizontal directional drilling (HDD) seeks to avoid the creek cut altogether by tunneling under the waterway. Each technique is associated with a particular set of environmental harms.

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[6] Johnson, et al. *supra* note 3, at 3.
[7] Craig R. Mccoy and Joseph Tanfani, *Similar Pipes, Different Rules*, PHILADELPHIA INQUIRER, available at, http://articles.philly.com/2011-12-12/news/30507185_1_hazardous-materials-safety-administration-pipeline-safety-rules.
[8] *Id*. at 1.
[9] Image available at, http://www.marcellus-shale.us/gas-pipelines.htm (picture of a well-pad and gathering line located in Amwel Township, Pennsylvania).
[10] Johnson, et al. *supra* note 3, at 3.

Wet ditch crossing construction is primarily accomplished through in-stream dredging. While this method is cheaper, quicker, and thus more common, it is also associated with more significant environmental problems than any of the dry ditch techniques. The process for wet ditch crossings involves laying pipe across a stream by digging a ditch from one side of the stream to the other. In some cases, a temporary bridge is installed so the backhoe can dig a trench across the streambed (see Figure 3[11]).[12] This construction occurs *as the stream is flowing*; there is no redirecting or damming of water. There are high releases of sediment, impacts to aquatic ecosystems, and changes in channel morphology.[13]

Figure 3: Picture of wet ditch crossing of the Lackawaxan West Branch River .

In the dam and pump technique, the stream is dammed and water is transferred across the construction site by means of a temporary hose or pipe and pump. This construction isolates and diverts the stream around the pipeline crossing. Problems associated with this technique include: sediment releases during dam construction, dam removal and as water washes over the construction area; slow construction/installation time compared to other construction methods; extended period of in-stream activity and prolonged sediment release; fish salvage may be required from dewatered reach; and a short-term barrier to fish movement is created.[14]

In the flume technique, the stream is dammed and a culvert is installed. The flume pipe is then installed after blasting (if necessary), but before any trenching. Sand bags and plastic sheeting diversion structures or an equivalent setup are often used to divert stream flow through the flume pipe. In addition to the problems posed by the dam and pump method, problems associated with flume pipeline construction include: the flumes becoming short-term barriers to fish passage if the water velocity in the flume pipe is too high or if the flume pipe is perched above the streambed; and the inducement of stream velocities that may create downstream scour.[15]

Horizontal directional drilling is a technique that is similar to the drilling of a horizontal hydraulic fracturing well. A pilot hole is first drilled down to a sufficient depth and then deviated underneath the stream parallel to the ground. The wellbore is then enlarged to a diameter larger than the diameter of pipe to be installed. A prefabricated pipe segment is pulled into the hole, using the same drill rig that bored the initial and enlarged holes. Although directional boring installations do not generate major sediment discharges, the potential for environmental damage due to unexpected releases of drilling mud and borehole cave-ins still exists.[16] If fractures in the drilling substrate are encountered, there is the potential for pressurized drilling fluids to leak out of the borehole and potentially reach the streambed.[17] For example, three separate blowouts or spills caused by Laser Pipeline Co. muddied a high value stream in Susquehanna County where horizontal directional drilling was utilized.[18] In 2013 the Tennessee Gas Pipeline company had a blow out during horizontal directional drilling of its Northeast Upgrade Project that collapsed a local

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[11] Picture courtesy of the Delaware Riverkeeper Network, Faith Zerbe, 2011.
[12] James Norman, et al., *Utility Stream Crossing Policy*, ETOWAH AQUATIC HABITAT CONSERVATION PLAN, July 13, 2008, 12.
[13] T.C. Pharris, R.L. Kopla, *Overview of the Design, Construction, and Operation of Interstate Liquid Petroleum Pipelines*, Argonne National Laboratory (2007).
[14] Norman, *supra* note 12
[15] Norman, *supra* note 12 at 13.
[16] Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association, and Canadian Gas Association, *Pipeline Associated Water Crossings*, 1-4 (2005).
[17] *Id*.
[18] Available at, http://thetimes-tribune.com/news/third-spill-at-pipeline-site-sullies-susquehanna-county-creek-1.1186532#axzz1iLfWwIBC.

road in Northern New Jersey[19] and caused a release of drilling muds. Additionally, fluid management problems and cross-contamination of aquifers may be a concern when aquifers of large-volume sources of groundwater under pressure are intersected by the pilot hole.[20] Horizontal directional drilling also requires large areas to be cleared for mud pits, pipe assembly areas, and staging areas and therefore has a significant disturbance footprint.

For a more thorough description of the different pipeline construction techniques, please see "Overview of the Design, Construction, and Operation of Interstate Liquid Petroleum Pipelines," by T.C. Harris and R.L. Kopla.[21]

III. Impacts of Pipeline Construction Activity

There are significant environmental impacts which result from pipeline crossing and construction activities regardless of mitigation techniques used. The list of impacts includes, but is not limited to: erosion and sedimentation, loss of riparian vegetation, habitat loss and fragmentation, air quality impacts, safety concerns, groundwater impacts, soil compaction, increased stormwater runoff, wetland degradation, and cumulative environmental impacts along the length of the project. These impacts to the environment are not limited to the time period in which the right-of-way is disturbed, but can result in long lasting consequences.

Sediment Pollution

Studies documenting the effects of stream crossing construction on aquatic ecosystems identify sediment as a primary stressor for construction on river and stream ecosystems.[22] During the construction of pipeline stream crossings, discrete peaks of high suspended sediment concentration occur due to blasting, trench excavation, and backfilling.[23] For example, the excavation of streambeds can generate persistent plumes of sediment concentration and turbidity.[24] This sedimentation has serious consequences for the benthic invertebrates and fish species whose vitality is crucial for healthy aquatic ecosystems. There have been documented reductions in benthic invertebrate densities, changes to the structure of aquatic communities, changes in fish foraging behavior, reductions in the availability of food, and increases in fish egg mortality rates.[25] In addition to the stream crossing construction activity itself, the associated new road construction increases the risk of erosion and sedimentation.[26]

There are numerous environmental risks associated with open trench burial of gas pipelines (wet, dry, slurry). Open trench burial involves the excavation of sediments for pipeline installation perpendicular to or across streams and their sometimes wide floodplains, along with removal of vegetation and well-established ecosystems. Disruption of the stream channel and banks can cause destabilization of the stream's natural flows, causing channel migration and erosion that are harmful to the stream. [27] The open trench cut method of crossing streams results in sedimentation, impacts to benthic habitat, and can result in changes to stream morphology that can further affect downstream habitats.[28]

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[19] Pipeline work collapses part of Sussex county road near Delaware river, North Jersey.com July 9, 2013. http://www.northjersey.com/news/pipeline-work-collapses-part-of-sussex-county-road-near-delaware-river-1.713363

[20] Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association, and Canadian Gas Association, *Planning Horizontal Directional Drilling for Pipeline Construction*, 6-3 (2004).

[21] T.C. Pharris, R.L. Kopla, *Overview of the Design, Construction, and Operation of Interstate Liquid Petroleum Pipelines*, Argonne National Laboratory (2007).

[22] Scott Read, *Effects of Sediment Released During Open-cut Pipeline Water Crossings,* Canadian Water Resources Journal, 1999, 24: (3) 235-251.

[23] *Id*.

[24] *Id*.

[25] Norman, *supra* note 12, at 9-10.

[26] *En Banc* Hearing of the Pennsylvania Public Utility Commission on Jurisdictional Issues Related to Marcellus Shale Gas Development, Docket No. I-2010-2163461.

[27] Expert Report from HydroQuest, attached.

[28] See Effects of Sediments Released During Open-Cut Pipeline Water Crossings, Canadian Water Resources Journal, Vol. 24, No. 3, 1999.

Sedimentation results from the actual crossing activity itself as well as the removal of vegetation and activity that takes place on the stream-adjacent (riparian) lands. While dam and pump methods, can reduce sediment loadings associated with a wet cut method, there are still sediment releases at levels of concern and impact, and the diversion of the water creates impediments to fish and flows that also have impacts on waterways. Additionally, this method of crossing takes longer, and so it results in longer-term direct impacts to the stream and sediment releases over a prolonged period. Sediment carried in the water column is abrasive and can result in increased erosion downstream.[29] Deposited sediment from construction activities can fill in the interstitial spaces of the streambed, changing its porosity and composition, and thereby increasing embeddedness and reducing riffle area and habitat quality.[30] Furthermore, deposited sediment has the potential to fill in pool areas and reduce stream depth downstream of the construction area.[31]

Impacts to Benthic Invertebrates, Fish Communities and Aquatic Ecosystems

Benthic invertebrates can have higher drift rates during stream crossing construction and reduced densities following open trench cut methods of crossing. Reduced densities can be the result of both the higher drift and the increased sedimentation that affects suitability of habitat resulting from the pipeline installation.[32] Changes in downstream diversity and structure of benthic invertebrate communities can also result. While, in time, the benthic community generally restores, that does not diminish or negate the ecosystem affects during the time of damage including the other cascading affects to other ecosystem services otherwise provided by the invertebrates – including as food for other dependent species, the water quality benefits provided by invertebrates helping with nutrient breakdown, and the breakdown of instream detritus creating food for other species.[33]

Using the open trench cut method of crossing can also affect fish, including direct harm but also by reducing the suitability of habitat including for eggs, juveniles and overwintering.[34] Fish exposed to elevated suspended solids levels can experience reduced feeding rates, physical discomfort or damage from the abrasive materials on their gills, decreased instream visibility, reduced food supply, and increased competition as fish attempt to move to cleaner waters.[35] For example, the filling of riffles not only can have adverse impacts for invertebrates and fish, in terms of taking important habitat, but it can also diminish the ability of the riffles to help create oxygen important for aquatic life.[36] Over time these impacts can depress the immune system of fish, result in lower growth rates, result in increased stress on individuals and populations, cause damage to the gills – all of which can result in a decline in fish and population health and survival rates.[37] This of course all gets compounded by adverse effects to the suitability of habitat for eggs and juveniles necessary to support the overall community and population.[38] Additionally, downstream sedimentation and also disruption of flows during crossing activities can result in areas of the stream that are shallower or dewatered, thereby taking preferred habitat.[39]

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29 Pipeline Associated Watercourse Crossings, 3rd Edition, publication prepared for CAPP, CEPA, and CGA by Tera Environmental Consultants
30 Read, *supra* note 22, at 235-251.
31 Norman, *supra* note 12, at 9-10.
32 Ibid 1.
33 See e.g. Sweeney, B. W., et al. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services, PNAS, September 2004; 101: 14132-14137.
34 Ibid 1.
35 Pipeline Associated Watercourse Crossings, 3rd Edition, publication prepared for CAPP, CEPA, and CGA by Tera Environmental Consultants
36 Ibid 1.
37 Ibid 1.
38 Ibid 1.
39 Ibid 1.

Riparian Forest Impacts

Pipeline construction results in the loss of riparian (streamside) vegetation.[40] For each of the pipeline construction techniques there is a resulting loss of vegetation and foliage associated with clearing the stream banks. Riparian vegetation is an important part of a healthy ecosystem and protects the land adjoining a waterway which in turn directly affects water quality, water quantity, and stream ecosystem health. A stream corridor is composed of several essential elements including the stream channel as well as associated wetlands and vernal ponds, floodplains, and forests. The body of scientific research indicates that stream buffers, particularly those dominated by woody vegetation that are a minimum 100 feet wide, are instrumental in providing numerous ecological and socioeconomic benefits. [41] Simply put, riparian corridors protect and restore the functionality and integrity of streams. A reduction in streamside healthy and mature streamside vegetation reduces stream shading, increases stream temperature and reduces its suitability for incubation, rearing, foraging and escape habitat.[42] While horizontal directional drilling may move the construction footprint further away from the stream, it too results in vegetative losses and soil compaction that can have direct stream impacts.

The loss of vegetation also makes the stream more susceptible to erosion events, exacerbating the sedimentation impacts of construction. In crossings that result in open forest canopies, increases in channel width, reduced water depth, and reduced meanders have persisted in the years after using an open cut method of installation.[43]

Habitat Fragmentation

Forest fragmentation and habitat loss is a serious and inevitable consequence of increased pipeline construction activity. When a pipeline cuts its path through a forest the level of harm is increased – the "forest clearing creates an associated edge effect" whereby "increased light and wind exposure creates different vegetation dynamics".[44] Therefore, damage to the forest ecosystem for a 1 mile section of a 100 foot wide pipeline right of way (ROW) will directly impact 12 acres of forest, and it will damage an additional 72 acres of adjacent forest by transforming it from interior habitat to that of forest edge habitat[45] (i.e. an additional 300 feet of forest on either side of the ROW is impacted). This means that when a forest cut is made, for every 1 mile of pipeline (assuming a 100 foot ROW) at least 84 acres of forest habitat are impacted.

The Nature Conservancy has determined that "[t]he expanding pipeline network could eliminate habitat conditions needed by "interior" forest species on between 360,000 and 900,000 acres as new forest edges are created by pipeline right-of-ways."[46]

Interior forest species, such as black-throated blue warblers, salamanders, and many woodland flowers, require shade, humidity, and tree canopy protection that only deep forest environments can provide.[47] For example, the ROW corridor "inhibits the movement of some species, such as forest interior nesting birds, which are reluctant to cross openings where they are more exposed to predators." [48] While some species may be inhibited from travelling up or across an open pipeline ROW, others will readily travel up and over, increasing the level of harm. The clearing of forest for pipelines can also result in the introduction of invasive species (such as Japanese knotweed and hay scented fern) resulting in further

[40] Norman, *supra* note 12, at 8.
[41] See e.g. Newbold et al. 1980, Welsch 1991, Sweeney 1992, Sweeney and Newbold 2014
[42] CAPP (2005), *supra* note 16, at 1-4.
[43] Ibid 1.
[44] Cara Lee, Brad Stratton, Rebecca Shirer, Ellen Weiss, *An Assessment of the Potential Impacts of High Volume Hydraulic Fracturing (HVHF) on Forest Resources*, The Nature Conservancy, Dec. 19, 2011.
[45] Johnson, *supra note* 3.
[46] Johnson, *supra note* 3.
[47] Johnson, *supra note* 3.
[48] Johnson, *supra note* 3.

decline of native wildlife species, and the creation of microclimates that degrade forest health through sunscald and wind-throw.

Prior to the development of Marcellus shale gas, Pennsylvania was already home to "an estimated 8,600 miles of large diameter natural gas pipeline."[49] The Nature Conservancy has estimated that every shale gas well pad results in approximately 1.65 miles of gathering pipeline.[50] This means that Marcellus shale gas development in Pennsylvania could require 10,000 to 25,000 miles of new gathering pipeline by the year 2030 (depending on whether one is assuming a low or high development scenario.)[51] It is estimated that a third to a half of this new pipeline will be built in the State's forested areas.[52] Nature Conservancy has projected that 60,000 to 150,000 acres of forest will be cleared in the next 20 years for pipeline rights of way.[53]

Air Quality Impacts

Shale gas, its development and use, results in greenhouse gas emissions of carbon dioxide and methane. Compressors and pipelines associated with shale gas are also sources of air pollution including methane, ethane, benzene, toluene, xylene, carbon monoxide and ozone.[54] The greenhouse gas footprint from shale gas during its development, storage and transmission is at best comparable to, and more than likely far worse than, that of other major fossil fuels.[55]

Methane is a primary component of natural gas. While carbon dioxide is the primary greenhouse gas emitted as the result of human activities, methane is the second most prevalent and is known to be significantly more potent than carbon dioxide in its adverse effects on global climate change. Compared to carbon dioxide, methane has a global warming potential that is as much as 34 times higher when considering a 100-year time frame. If a 20-year time frame is used, the figure goes up with the global warming potential of methane being 86 times greater than CO^2. Given that the earth may reach a temperature tipping point in anywhere from 18 to 38 years,[56] it is the 20 year time frame that is the most meaningful and needs to be the basis of present day decision-making.

"Natural gas systems are the single largest source of anthropogenic methane emissions in the United States" contributing approximately 40% of the anthropogenic emissions of methane.[57] Emission of methane to the atmosphere during the production and distribution of shale gas contributes to this fossil fuel's climate changing impacts. Methane is released to the atmosphere on multiple occasions during the shale gas extraction process. It has been estimated that "during the life cycle of an average shale-gas well, 3.6 to 7.9% of the total production of the well is emitted to the atmosphere as methane."[58] Among the most recent scientific findings is that as much as 9% of the methane produced while drilling for gas is lost to the atmosphere.[59] While a previous estimation that 4% was lost from the well fields had already raised alarm bells for many;[60] the new figure of 9% is increasing evidence of the massive methane contribution shale gas development provides to the atmosphere.

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[49] Johnson, *supra note* 3.
[50] Johnson, *supra note* 3.
[51] Johnson, *supra note* 3.
[52] Johnson, *supra note* 3.
[53] Johnson, *supra note* 3.
[54] Johnson, *supra note* 3.
[55] R.W. Howarth, R. Santoro, A. Ingraffea, Methane and the greenhouse-gas footprint of natural gas from shale formations, A letter, Climatic Change, March 13, 2011.
[56] R. Howarth, D Shindell, R. Santoro, A. Ingraffea, N. Phillips, A Townsend-Small, Methane Emissions from Natural Gas Systems, Background Paper Prepared for the National Climate Assessment, Reference number 2011-0003, Feb. 25, 2012.
[57] Id.
[58] Howarth, *supra note* 55.
[59] Methane Leaks Erode Green Credentials of Natural Gas, Nature International Weekly Journal of Science, Jan. 2, 2013. See also Howarth, *supra note* 56
[60] Id.

Additionally, large amounts of methane leak into the atmosphere during the "transport, storage and distribution" phases of the natural gas delivery process including during transmission through interstate pipelines.[61] Even conservative estimates of leakage during gas transmission, storage and distribution have given a range of up to 3.6%.[62] If additional processing is required before the gas can be transported through a pipe then as much as 0.19% more of the gas can be lost. [63] The majority of emissions from the transmission segment come from leaks on compressor components. Leaks of methane from the pipelines are also caused by disturbances from earth movement, the breakdown of joints, corrosion, and natural processes that degrade softer elements in the pipe. After the gas moves through transmission lines, underground distribution pipelines move the gas from the local gas utility/ distribution company to the end user, the residential or commercial customers. High incidence of leaks also occur from underground distributions pipelines especially from older pipelines made of cast iron and unprotected steel. Since Pennsylvania, New Jersey, and New York have the greatest miles of both cast iron and unprotected steel distribution pipelines,[64] leakage from distribution lines may be significant.

Researchers "have found that methane leaks would need to be held to 2% or less in order for natural gas to have less of a climate changing impact than coal due to the life cycle of methane."[65] At leakage above 3.2%[66] natural gas ceases to have any climate advantage over other fossil fuels. As discussed above, the existing leakage rate is likely significantly higher than either of these numbers.

When upstream and downstream emissions are considered along with the increase in shale gas wells over the next 2 decades, the methane emissions from the natural gas industry will increase, by as much as 40 to 60%.[67] Upstream emissions occur during well completion and production at a well site while midstream emissions occur during gas processing. Downstream emissions are those that happen in the storage systems as well as the transmission and distribution pipelines. [68]

Scientists believe that if the earth warms to 1.8^{o}C above what it was between 1890 and 1910 that it will put in play a set of chain reactions that will result in increasing releases of methane to the atmosphere – largely released from the arctic as a result of melting permafrost – which will in turn cause increased warming and its associated impacts.[69] It is posited by scientists that without immediate reductions in methane emissions and black carbon the earth will warm to 1.5^{o}C by 2030 and 2.0^{o}C by 2045/2050 and that this will be the case regardless whether carbon dioxide emissions are reduced or not. And so it is clear that the next few decades are crucial, and that reduction of methane in the near term must be part of any solution.

Exposed Pipelines and Associated Risk of Rupture

Because open trench pipeline installations may unnaturally alter both stream bank and streambed (i.e., channel) stability, there is an increased likelihood of scouring within backfilled pipeline trenches. This is because open trenches themselves, when backfilled, may not be compacted to stable pre-trench sediment permeability conditions. Flooding rivers can scour river bottoms and expose pipelines to powerful water currents and damaging debris. Additionally, unusually heavy rains possibly associated with climate change, threaten to increase overall stream degradation and channel migration – thereby exposing shallowly buried pipelines.

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[61] Howarth, *supra note* 56; See also U.S. EPA 1997. Methane Emissions from the Natural Gas Industry. USEPA National Risk Management Research Laboratory, June 1997, EPA-600-SR-96-080.
[62] Howarth, R. W. (2014). A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas. Energy Science & Engineering.; See also Howarth, *supra note* 55.
[63] Howarth, *supra note* 55.
[64] U.S. EPA 2014. Improvements needed in EPA efforts to address methane emissions from Natural gas Distribution pipelines. Office of Inspector General. Report 14-P-0324. July 25, 2014.
[65] ***Switching from Coal to Natural Gas Would Do Little for Global Climate, Study Indicates***, UCAR/NCAR Atmos News, Sept 8, 2011.
[66] According to the Environmental Defense Fund
[67] Howarth, *supra note* 56.
[68] Howarth, *supra note* 56.
[69] Howarth, *supra note* 56.

Scouring that exposes pipelines buried in streambeds is well documented. The open trench cut method is likely to set the pipeline shallowly enough that exposure by scour is a real threat. Exposure of the pipeline raises a greater risk of pipeline damage, breakage and pollution; with pipeline breakage resulting in the catastrophic discharge of its contents into the natural stream system. Talke and Swart (2006) and De La Motte (2004) discuss gas pipelines and how man-made changes and actions have altered channel morphology and changed channel stability. Soil erosion and channel migration reduces the soil cover over a pipeline, resulting in scour hole formation and making the pipeline vulnerable to rupture. Lateral migration of stream channels can also heighten the risk of pipeline exposure. Fogg and Hadley (2007) evaluated hydraulic considerations for pipeline crossings stream channels. Their Figure 4 depicts lateral migration of a stream channel during high water that excavated a section of pipeline under the floodplain that was several feet shallower than at the original stream crossing.

Figure 4: Picture of an exposed pipeline crossing an unnamed western US river.

Scour hole development proximal to pipelines is well-documented in both stream and seabed settings.[70] In 1993, the flooding Gila River in Arizona ruptured a 36-inch pipeline, sending natural-gas bubbling to the surface.[71] In addition, and also associated with 1993 flooding in Arizona from heavy water releases from San Carlos Lake, several El Paso Natural Gas pipelines, which crossed the Gila River near Coolidge, Winkleman, and Kelvin were "scoured" and uncovered by the force of the water and failed.[72] Doeing et al. (1997)[73] further document six gas pipelines in the Gila River Basin that were either exposed on bridges or failed due to stream erosion stemming from January 1993 floods in Arizona. The failures were critical because these were major transmission lines that supplied natural gas to residential and industrial users in whole communities and groups of communities. Stream-based pipe *"(f)ailures were caused not only by vertical scour of the streambed but also by bank erosion, lateral channel migration, avulsions, bridge scour, and secondary flows outside the main channel. … Several of the pipelines in the study failed as a result of a meander migration or avulsion of the stream into previously less active or nonexistent channels*."[74] Based on field observations and hydraulic modeling for the 100-year design flood, researchers documented maximum vertical scour to 26.6 feet (8.1 meters) and lateral scour to 6,274 feet (2,050 meters) at some failed pipeline crossings.

Federal regulations require that pipelines crossing rivers be buried at least four feet underneath most riverbeds.[75] An expert at HydroQuest has determined that, at a minimum, any pipeline installed using the open trench cut method needs to be installed at least 24 feet below the stream bed in order to prevent exposure from scour.[76] While bridge piers are more readily exposed to stream scouring than pipelines, it is telling that bridge failure analyses have determined that channel scour occurs to depths of up to three times that of maximum river floodwater depth (e.g., scour to 30 feet with a 10 foot floodwater depth).

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[70] Fogg, J. and Hadley, H., 2007, Hydraulic Considerations for Pipelines Crossing Stream Channels. Technical Note 423. BLM/ST/ST-07/007+2880. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 20 pp. http://www.blm.gov/nstc/library/techno2.htm.
[71] Randazzo, R., 2010, Arizona to assess gas- pipe safety after California blast. The Arizona Republic (9-20-10).
[72] Wikipedia. http://en.wikipedia.org/wiki/Coolidge_Dam
[73] Doeing, B.J., Williams, D.T. and Bradley, J.B., 1997, Gas Pipeline Erosion Failures: January 1993 Floods, Gila River Basin, Arizona. In Storm - Induced Geologic Hazards, Case Histories from the 1992 - 1993 Winter in Southern California and Arizona; Geological Society of America; Reviews in Engineering Geology, Volume XI (ed. Robert A. Larson).
[74] Id.
[75] Billings Gazette, July 21, 2011: http://billingsgazette.com/news/state-and-regional/montana/article_c8d20d9e-b391-11e0-941f-001cc4c002e0.html
[76] Expert Report from HydroQuest.

Another significant environmental risk associated with both wet and dry trench methods of gas pipeline crossings of rivers and streams is the potential of releasing hydrocarbons or other contaminants directly into surface water and fragile downstream ecosystems, including hydro-carbon laced liquids such as benzene that are part of the gas being delivered by the pipeline. Gas, as it is extracted from a well, may be mixed with hydraulic fracturing fluids. Hydrocarbon-laced condensate or natural gas liquids (NGLs) associated with natural gas (e.g., benzene) pose an environmental risk if pipe rupture occurs (e.g., to potential bog turtle habitat and travel corridors, fisheries, downstream drinking water supplies as well as underlying aquifers recharged by stream water). For example, a damaging flood event in Texas ruptured eight pipelines and spilled more than 35,000 barrels of oil and oil products into the San Jacinto River.[77] The Bureau of Land Management recognized and addressed this critical issue: *"In 2002, the U.S. Fish and Wildlife Service raised concerns about the potential for flash floods in ephemeral stream channels to rupture natural-gas pipelines and carry toxic condensates to the Green River, which would have deleterious effects on numerous special-status fish species".*[78]

Figure 5: Picture of an exposed pipeline crossing the Green River Utah.

Clean up associated with pipeline breaks can be extremely expensive. For example, ExxonMobile expects that cleanup costs associated with fouling an estimated 70 miles of shoreline of the Yellowstone River may cost about $135 million.[79] The Department of Environmental Quality in Montana is also concerned with thousands of pipelines that cross small or intermittent streams. Federal officials investigating a July 2011 pipeline break that spilled 1,500 barrels of oil into a Montana river said that few companies take river erosion and other risks into account when evaluating pipeline safety.

Groundwater Impacts

Pipelines have been seen by experts to be conduits for diverting groundwater from its natural path. According to expert observation, pipeline trenches can divert groundwater and as a result "permanently alter the hydrologic cycle in the vicinity of the pipeline right-of-way. This alteration will decrease the water resources available to support wetland hydrology and stream base flow in the summer and fall dry season."[80] For example, observations of the Tennessee Gas Pipeline's 300 Line Upgrade project by a hydrologist determined that "pipeline trenches intercepted shallow groundwater in places, creating preferential paths for dewatering shallow groundwater not just in the disturbed construction areas, but also in areas surrounding the right-of-way, further negatively impacting ground water resources and wetlands."[81] As a result, it was observed that the 300 Line Upgrade pipeline project had "already resulted in permanent changes to wetlands…."[82]

The compacted soils resulting from pipeline construction increase rainfall runoff and reduce ground water infiltration. This can cause further negative impacts on wetland hydrology and stream baseflow in the

[77] Billings Gazette, *supra note* 75.
[78] Fogg and Hadley, *supra note* 70.
[79] Billings Gazette. Feb. 8, 2012: http://billingsgazette.com/news/local/feds-few-pipeline-plans-account-for-river-risks/article_b2ecac80-d313-53c9-a914-906a97aedb9d.html?oCampaign=hottopics
[80] Affidavit of Peter M. Demicco, DRN v. PA DEP an TGP NEUP, 2012.
[81] Id.
[82] Id.

area of the pipeline.[83] "Increased runoff as a result of compacted soils, and increased drainage of shallow ground water" around a pipeline, due to previous and proposed construction practices, can increase "surface water flow and groundwater discharge in the wet winter and spring seasons and decrease summer and fall ground water discharge which supports wetland hydrology and stream base flow."[84] The result of reduced groundwater discharge during the dry summer and fall months can be to decrease the size of supported wetlands. So the result is too much or too little depending on the time of year. Another result of the altered flows can be to decrease stream base flow that supports aquatic life and trout habitat in headwater streams in the dry summer and fall period.

Wetlands Impacts

Pipeline construction activity requires the clearing of vegetation in and around wetlands having degrading impacts. After a new right-of-way is cleared, or an existing one is expanded, pipeline companies maintain the right-of-way by preventing woody vegetation from re-establishing on the right-of-way. As such, pipeline construction activity that passes through forested wetlands result in the permanent conversion of the forested wetland to an emergent wetland. This conversion adversely impacts the functions and values of a wetland.

Certified wetlands specialists have found a measurable "decrease" or "loss" in functionality as a result of the permanent conversion of forested wetlands to emergent wetlands.[85] For example, a functional conversion of wetlands from forested wetlands to emergent wetlands generally result in decreases to above ground biomass, structural diversity of the wetland, and local climate amelioration.[86] The conversion will also result in a loss of forest interior habitat, visual and aural screening from human activity, suitability of shade-loving plant species, and the production of mast (such as acorns) for wildlife.[87] Moreover, these conversions also result in increased wetland exposure to wind, ice and sun, as well as the localized effects of global warming on biota.[88]

Wetland functions involving drainage patterns, water quantity, and water quality will also be adversely impacted by a functional conversion of forested wetlands to emergent wetlands. Specifically, emergent wetlands provide decreased soil stabilization, streambank anchoring against erosion, nutrient storage, and temperature maintenance when compared to forested wetlands.[89] As a result, erosion and sedimentation can be expected to increase as a result of the conversion.[90] The function of storm damage shielding can also be expected to decrease as a result of this conversion.[91]

Cumulative Impacts

The large amount of land disturbance created during pipeline construction results in increased stormwater runoff, sedimentation, and erosion of the land and stream channels.

The cumulative impact of multiple construction sites for water crossings on a stream or river has the potential to significantly degrade the quality and flow rate of the waterbody. The capacity of a water system to recover from a multitude of impacts may be exceeded with the detrimental effects of crossing

[83] Id.
[84] Id.
[85] *See, generally* The Effects of Converting Forest or Scrub Wetlands into Herbaceous Wetlands in Pennsylvania: A Report to the Delaware Riverkeeper Network, Schmid and Company, Inc., Consulting Ecologists (2014), attached.
[86] Id.
[87] Id.
[88] Id.
[89] Id.
[90] Id.
[91] Id.

construction becoming permanent.[92] Recurrent stresses on fish, such as those originating from elevated suspended sediment concentrations, will have negative effects on fish health, survival and reproduction.[93]

Broadly speaking, pipeline ROWs have two kinds of impacts: catastrophic events and chronic impacts.[94] Current regulation focuses mainly on preventing or minimizing harms that are of the catastrophic event kind – such as siltation during construction, erosion from runoff, increased stormwater runoff resulting during or after construction; but the larger ecological harms of pipeline construction is not given the same kind of consideration in current regulation. [95] Forest fragmentation, edge effects, adverse impacts to the quality of adjacent forest, the intrusion of invasive species, and the cumulative impacts of shale gas developments that results from and/or is supported by pipeline construction are all issues generally ignored in current regulation.[96] Other harms in need of greater attention in regulation includes the increased soil compaction resulting from current construction practices, the dewatering of groundwater sources, and impacts to the quality of the adjacent forest and biodiversity.

There are serious permanent environmental problems associated with pipelines. Pipelines are significant contributors to air pollution and climate change. Additionally, the potential of pipelines to rupture and leak raises a greater risk of human health concerns and serious water contamination issues. Pipelines also divert and diminish groundwater flows.

Gas pipelines are installed by private competing companies, and there is no regulatory body ensuring that these pipeline delivery systems are rationally designed, apportioned, operated, or maintained. As private companies, each of these operators has competing interests, and thus are characterized by aggressive business strategies rather than norms of shared use, cooperation, and integration. There is a danger this atmosphere will be reflected in not only the pace, size, and scope of development; but also in the way in which it occurs.

The current legal regime is not properly equipped to handle the exponential increase in concentration of pipeline construction in the Delaware River Basin. A number of federal and state agencies have been tasked with monitoring these activities, but to date have simply overseen numerous permit violations, pollution events, and noncompliant construction activity without having issued stop-work orders or appropriate fines to the associated operator. The Delaware River Basin Commission has clear authority to regulate in this arena, as enunciated in Article three of the Delaware River Basin Commission Compact; however, to date the Commission has failed to exercise this authority but Delaware Riverkeeper Network is working to change that.

For a more expansive overview of potential cumulative environmental impacts please see, Utility Stream Crossing Policy, by James Norman, et al.[97]

Ongoing Impacts of Pipelines

In addition to the immediate impacts of construction, the ROW will need to be maintained and kept clear throughout the lifetime of the pipeline, which can be up to 80 years (See figure 6,[98]). While some companies assert they only keep 50 feet of the original construction ROW open for future monitoring, maintenance and repairs of the pipeline[99], the Delaware Riverkeeper Network has found that interstate transmission lines tend to be much wider – either by design or because the level of compaction that takes

[92] CAPP (2005), *supra* note 16, at 1-4.
[93] CAPP (2005), *supra* note 16, at 1-4
[94] Kevin Heatley, Restoration Ecologist, Professional Review & Comment on Natural Gas Pipeline Impacts to Terrestrial Ecology prepared for Delaware Riverkeeper Network, Sept 5, 2012.
[95] Id.
[96] Id.
[97] Norman, *supra* note 12, at 11-13.
[98] Image courtesy of Delaware Riverkeeper Network, Faith Zerbe.
[99] Johnson, *supra note* 3.

place during construction is so dense it prevents restoration of healthy vegetated habitat. And increasingly pipeline companies are planning for wider widths, 100 to 200 feet, to be kept permanently open (free from mature vegetation) for the life of the project.

Pipelines also bring with them compressor stations, necessary for moving the gas within the pipeline, as well as other infrastructure such as shutoff valves. Each compressor station site occupies an "average area of slightly over 5 acres." [100] Thereby increasing further the size of the permanent pipeline footprint.

Additionally the air quality impacts associated with methane leakage, the stormwater runoff and loss of groundwater recharge associated with vegetation loss and soil compaction, the impacts of forest fragmentation and invasive species are also enduring.

Figure 6: Picture of a natural gas pipeline construction in Pike County, Pennsylvania.

IV. Conclusion

With the increase in natural gas drilling activity in Pennsylvania and elsewhere, it can be expected that the surrounding areas will experience a surge in the development of supporting infrastructure. Federal and state agencies – as well as pipeline project sponsors – must be held accountable for addressing the various impacts described above. Pipeline construction and operational activity is a zero-sum game that will result in long lasting impacts to the surrounding environment. It is the mission of the Delaware Riverkeeper Network to protect the natural resources of the Delaware River Basin to the greatest extent possible from the encroachment of fossil fuel development activities.

[100] Johnson, *supra note* 3.