August 16, 2014

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

Subject: Docket #PF14-8: Scoping Comment for the EIS for William's Atlantic Sunrise Project

Dear Ms. Bose,

This comment by Delaware Riverkeeper Network (DRN) supplements the oral testimony DRN provided on August 5, 2014 at the FERC public scoping meeting in Lebanon PA on the proposed Atlantic Sunrise (AS) project. DRN submits the following comments on the scope of the Environmental Impact Statement (EIS) to be prepared by the Federal Energy Regulatory Commission (FERC) with respect to the proposed AS Project proposed by Transco/Williams. Thank you for the opportunity to provide comments regarding the short term, long term and irreparable environmental and community impacts this large gas infrastructure project would cause to the community.

The Atlantic Sunrise (AS) Project is proposed to add 1,700,000 dekatherms per day (dt/day) to Transco's pipeline capacity. According to company website and FERC scoping presentations: "The preliminary project design includes a total of approximately 178 miles of new greenfield pipe (new ROW) (Central Penn North & Central Penn South), two pipeline loops totaling about 12 miles (Chapman Loop, Unity Loop), two and half miles of existing pipeline replacement, two new compressor facilities in Pennsylvania, and other facility additions or modifications in five states (Pennsylvania, Maryland, Virginia, North Carolina, South Carolina)."

DRN has witnessed and monitored FERC approved gas pipeline projects first hand in Pennsylvania, New Jersey and New York the past several years and based on those field observations, the peer-reviewed science and white papers available regarding harms of natural gas extraction and gas infrastructure transportation projects, and regulatory limitations, loopholes, exemptions, expedience for which variances are provided, poor mitigation, and ineffective compliance we have observed with these gas projects, and the great harm this new pipeline ROW project would cause to the community and the environment, we believe the best and only option for the public and the community is for FERC to select a no build alternative for this project. DRN believes that if FERC performs a thorough Environmental Impact Statement (EIS) that is required for this project due to its extensive impact, FERC will come to select the no build alternative and not issue a Certificate of Public Necessity for the AS project. Furthermore, if FERC considers alternatives

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to gas infrastructure build out of this project, it must consider alternative and renewable energy sources, such as wind and solar sources, both small scale and large scale.

DRN also requests FERC provides a longer public input process since this gas infrastructure project is so extensive and would impact such a large area – the greenspring pipeline section of this project alone is approximately 178 miles in length and would cut through over 8 counties in PA to create a brand new industrial right of way cut for moving Marcellus Shale gas (ROW). A thirty day comment period is simply inadequate for the public to be informed and have the time to provide needed input for a thorough EIS. Furthermore, the summer months, especially the month of August, is often a time when the public is attempting to have vacation and time in the summer with family, so the timing is seen far from ideal to receive the needed public input to inform this process and a thorough EIS.

FERC must conduct a full, comprehensive, and credible Environmental Impact Statement ("EIS"), one that includes (but is not limited to):

1) Analysis of the "upstream" and "downstream" damage that AS would trigger via induced hydraulic fracturing activities and gas infrastructure development that this pipeline project would exacerbate. Cradle to grave and the entire energy intensive and expansive life cycle this extractive natural gas industry requires must be considered completely and in full in the EIS. This would include (but not be limited to) all direct pollution and impacts from fracking but not be limited to indirect air, water and land pollution from diesel truck trips required to frack wells (1,000 diesel truck trips to frack one well), generators used on site for dewatering during construction, the energy to move freshwater and flowback water needed and consumed in the process, the additional carbon released from destruction of forests and wetlands to build gas pad sites, additional stormwater impacts such as thermal impacts to nearby waterbodies that would in turn impact the natural benthic communities, causing less denitrification and other impacts to water quality and drinking water supplies, increased sedimentation to waterbodies, compaction of soils; impact of mining, production and transport of raw materials and completed equipment, like the steel pipelines that often come from foreign countries, required for the industry, silica/sand mining impacts for frack sand, etc.

2) Account for the cumulative, lifecycle greenhouse gas emissions AS would trigger, including the documented emissions from fracking wells, flaring, pipeline leakage, compressor stations, and tanker ships transporting LNG and the energy and subsequent emissions needed to cool methane gas to liquid for shipment. Again indirect impacts of less carbon sequestration in compacted soils and forests that are cut for these projects must also be included in these greenhouse calculations and must also include downstream impacts such as proposed Cove Point LNG facility and the addition and upgrades of other connector pipelines that would be needed if AS were built.

3) Include an independent, quantitative risk assessment of explosion hazards that could reach nearby homes and include an assessment of the radioactive nature and community impacts of methane gas from Marcellus shale and its impacts of this gas being transported and entering people's homes for consumption

The National Environmental Policy Act and its implementing regulations, 40 C.F.R. §§ 1500–08, make clear that federal agencies must consider the direct, indirect, and cumulative impacts of considered

Projects, including all connected, cumulative, and similar actions. 40 C.F.R. §§ 1508.8, 1508.25. The CEQ regulations implementing NEPA, which are binding on federal agencies provide that actions are connected if they:

(i) Automatically trigger other actions which may require environmental impact statements.
(ii) Cannot or will not proceed unless other actions are taken previously or simultaneously.
(iii) Are interdependent parts of a larger action and depend on the larger action for their justification.
Id. § 1508.25(a)(1).

- "Similar actions" are those that "have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* § 1508.25(a)(3). The regulations also provide that agencies should analyze similar actions in a single impact statement "when the best way to assess adequately the combined impacts of similar actions or reasonable alternatives is to treat them in a single impact statement." *Id.*
- Direct impacts "are caused by the action and occur at the same time and place." 40 C.F.R. § 1508.8.
- Indirect impacts "are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. . . . Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems." *Id*.
- Cumulative Impacts are: impact[s] on the environment which result[] from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. 40 C.F.R. § 1508.7. In preparing an EA adequate to support a FONSI, agencies must adhere to the CEQ standards outlined above. *See Kern v. U.S. Bureau of Land Mgmt.*, 284 F.3d 1062, 1076 (9th Cir. 2002)

For review and reference for this Docket, DRN is submitting and will attach comments to FERC submitted for the proposed Cove Point Facility and the Leidy Line since the AS would be connected to these projects. Since in its review of the AS project FERC may not limit its review of cumulative impacts by partitioning the Cove Point project from other sufficiently connected projects. "Segmentation" is the unlawful practice whereby a project proponent avoids the NEPA requirement that an EIS be prepared for all major federal actions with significant environmental impacts by dividing an overall plan into component parts, each involving action with less significant environmental effects. *Taxpayers Watchdog v. Stanley*, 819 F.2d 294, 298 (D.C. Cir. 1987) ("Taxpayers"). Federal agencies may not evade their responsibilities under NEPA by "artificially dividing a major federal action into smaller components, each without a 'significant' impact." *Coal on Sensible Transp. v. Dole*, 826 F. 2d 60, 68 (D.C. Cir. 1987). *See also* 40 C.F.R. § 1508.27(b)(7).

The general rule is that segmentation should be "avoided in order to ensure that interrelated projects, the overall effect of which is environmentally significant, not be fractionalized into smaller, less significant actions." *Town of Huntington v. Marsh*, 859 F.2d 1134, 1142 (2d Cir. 1988). Without this rule, developers and agencies could "unreasonably restrict the scope of environmental review." *Fund for Animals v. Clark*, 27 F. Supp. 2d 9, 16 (D.D.C. 1998) ("Fund").

To determine whether a project has been unlawfully segmented, "courts have considered such

factors as whether the proposed segment (1) has logical termini; (2) has substantial independent utility; (3) does not foreclose the opportunity to consider alternatives[.]" *Taxpayers*, 819 F.2d at 298. Courts consider "independent utility" in concert with other factors, including economic interdependence, timing, and geographic proximity.

The D.C. Circuit recently clarified the way in which it applies segmentation analysis to large scale development infrastructure projects. *See Delaware Riverkeeper, et al., v. U.S. F.E.R.C.*, (D.C. Cir., June 6, 2014). As a result of the Court's holding in the *Delaware Riverkeeper* case FERC may not treat separate gas infrastructure projects proposed in close temporal and spatial proximity to a proposed project as separate for NEPA review purposes. In *Delaware Riverkeeper*, the disputed project was the third of four pipeline construction projects completed in rapid succession by Tennessee Gas and Pipeline Company to upgrade an existing pipeline. Tennessee separately submitted four applications for the pipeline improvement projects to the Federal Energy Regulatory Commission ("FERC"). The Court found that FERC failed to consider the impacts of the four interdependent pipeline improvement projects, and assess the cumulative significant impacts of those projects.

Importantly, the Court found that the physical, functional, and temporal nexus between the projects militated toward finding that the project lacked substantial independent utility. In other words, the fact that the four projects were physically and functionally reliant upon one another combined with the common overlapping timing of the projects rendered them sufficiently connected for review pursuant to NEPA. This review necessarily includes a review of the cumulative impacts of the four projects, which must involve a consideration beyond statements that construction impacts will be "temporary" and will be "separated by time and distance."

Additionally, the Court specifically rejected FERC's argument that the "substantial independent utility test" is satisfied by the individual shipping contracts for each of the projects. The Court succinctly notes: Tennessee Gas could have proposed two-mile segments, or one-mile segments, or one hundred yard segments for NEPA review, so long as it produced shipping contracts in anticipation of the increased capacity attributable to each of these new segments. To interpret the "substantial independent utility" factor to allow such fractionalization of interdependent projects would subvert the whole point of the rule against segmentation. Therefore, in review of AS, and as a result of the Court's holding in *Delaware Riverkeeper*, FERC may not treat separate interstate natural gas pipeline projects proposed in close temporal and spatial proximity to inter-reliant projects as separate for NEPA review purposes.

Environmental Impacts from AS Pipeline Construction and Operation Are Directly Related to the Cove Point LNG Facility, the Transco Leidy Southeast Project and Other Related Paths - These Related Projects Must Be Considered In the EIS for AS

The Delaware Riverkeeper Network understands that a number of pipelines passing through the Delaware River watershed and other regions just outside of the Delaware River Basin are intended to transport shale gas that would likely be connected to the AS pipeline. The AS would also provide gas to the proposed Cove Point LNG facility in MD and possible LNG facilities on the Gulf Coast, according to Transco presentations and maps provided. These pipeline projects and associated compressor stations and LNG facilities are clearly related, foreseeable, and should be considered as part of the cumulative impact analysis that is part of the EIS and NEPA process for AS.

Leidy Southeast Expansion Project proposed by Transco and currently before FERC for consideration and review, would transport 525,000 dekatherms per day (dt/day) of natural gas from receipt points on Transco's Leidy Line in Pennsylvania to various delivery points along Transco's Mainline and Leidy systems in Pennsylvania and New Jersey including for ultimate delivery to, and export from, Cove Point LNG. Transco proposes that in order to transport this volume of natural gas it must construct approximately four separate loops of pipeline totaling 28.36 miles of 42-inch diameter pipeline, adding of 92,700 horsepower (hp) at four existing compressor stations, and modifying of various other aboveground facilities.

The environmental disturbance related to the proposed Leidy SE Line is substantial. For example, along just one the proposed four proposed loops, the Franklin Loop, construction activity will result in the disturbance of 59.66 acres of land within the existing maintained easement and 144.58 new acres outside the existing maintained easement, for a total disturbance of 204.24 acres of land. Stream crossings are planned as temporary disturbance at 33 currently acknowledged locations (plus at least two additional headwater streams), all in Special Protection waters having uses designated as Exceptional Value ("EV") or High Quality-Cold Water Fishery, Migratory Fishery ("HQ-CWF, MF"). Waters in Pennsylvania with Exceptional Value designated uses are equivalent to Outstanding National Resource Waters in the language of the federal Clean Water Act (33 USC § 1251 *et seq*.; 40 CFR 131.12). The Applicant identifies direct impacts to 17.37 acres by intended construction within 36 numbered wetlands.

On 1 April 2013, Dominion filed an application with FERC (Docket Number CP13-113) for expansion of the Cove Point facilities for gas liquefaction and export. The proposed expansion is projected to cost $3.4 billion to $3.8 billion.

According to Transco's Feb 2012 presentation titled Transco's Atlantic Access Project, anchor shippers using the Butler Path, Rivervale Path, and the Natrium path may all be linked to the proposed AS pipeline project so infrastructure and impacts from these three projects must also be considered in the EIS if they link up to AS. The Natrium pipeline path would provide up to 900,000 dt/d of firm transportation capacity in Transco's Zone 6, 5, 4, and 3. The path begins at a proposed interconnection with Dominion's gas treatment plant in Marshall County, WV ("Natrium") and extends through a new line to be constructed by Transco eastward across Pennsylvania to Transco's mainline at Station 195 in York County, PA ("Natrium Line"), and then continues southward on the mainline to a terminus at the existing Zone 3 interconnection with Liberty Gas Storage in Beauregard Parish, LA.

The Butler path provides up to 600,000 dt/d of firm transportation capacity in Transco's Zone 6, 5, 4, and 3. The Path begins at an interconnection with (location TBD) in Butler County, PA ("Butler") and extends through a new line to be constructed by Transco southward to an interconnection with the Natrium Line and from there across Pennsylvania to Transco's mainline at Station 195 in York County, PA, and then continues southward on the mainline to a terminus at the existing Zone 3 interconnection with Liberty Gas Storage in Beauregard Parish, LA. Path includes secondary rights on Transco Mainline and Leidy Line.

The Rivervale Path Provides up to 300,000 dt/d of year-round firm transportation. The Path begins at an existing supply interconnection point with Tennessee Gas Pipeline in Bergen County, NJ and extends southward on Transco's Mainline to Liberty Interconnect in Beauregard Parish, LA.

In Transco's Feb 2012 presentation and maps, it appears that part of the AS route would also lead to two proposed LNG facilities on the Gulf Coast in addition to the proposed Cove Point facility on the East Coast. This pipeline

Finally, just last week shortly after the release of the Leidy EA, a new pipeline proposal, the Penn East Gas Pipeline was unveiled to possible impacted landowners. The company said that the pipeline they are proposing would traverse four counties in Pennsylvania before crossing the Delaware River and into western Hunterdon Co NJ and dropping to the Hopewell Valley area of Mercer County, NJ (http://www.nj.com/hunterdon-county-democrat/index.ssf/2014/08/letters_in_the_mail_to_landown.html)

All of these projects appear to meet the temporal, physical, and functional requirements as articulated in *Delaware Riverkeeper* to be considered in the NEPA review process for the AS Project. For example, an examination of the proposed projects' timelines reveals that the Leidy SE Line and the AS projects will involve overlapping construction time periods with the Cove Point facility. Second, the Project applicant/Dominion has not demonstrated that the Cove Point LNG facility could operate as designed but for the completion of the proposed pipeline projects. The project applicants for the pipelines have similarly failed to show that the proposed pipelines would be financially viable without the offtake of capacity at the Cove Point facility. Without a demonstration that each of these projects could stand alone financially and physically FERC must include the associated pipeline project and the Cove Point LNG facility in any NEPA review of AS Pipeline Project.

Impacts to streams and water quality must be considered in the EIS

Moreover, published environmental studies demonstrate that pipeline construction activities result in four primary impacts to groundcover affecting water resources, including: erosion and sedimentation, loss of riparian vegetation, forest and habitat loss and fragmentation, and cumulative impacts. FERC must sufficiently include these well documented primary impacts in the EIS for the AS project.

Studies documenting the effects of stream crossing construction on aquatic ecosystems identify sediment as the primary stressor for construction on river and stream ecosystems. During pipeline stream crossing construction, discrete peaks of high suspended sediment concentration occur during activities such as blasting, trench excavation, and backfilling. The excavation of streambeds can generate persistent plumes of sediment concentration and turbidity. This sedimentation has serious consequences for the benthic invertebrates and fish species whose survival 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. In addition to the stream crossing construction activity itself, the associated new road construction increases the risk of erosion and sedimentation.

Many of the sediment and erosion control best management practices used during pipeline construction are not designed to be protective during significant rain events. For example, heavy rains during two tropical storms in August and September of 2011 caused extensive failures to erosion and sediment controls on pipelines under construction in north central Pennsylvania resulting in environmental harm from sedimentation plumes in nearby water resources. With impacts of climate change and catastrophic climate destabilization, more extreme weather events and storm events have become a regular occurrence and these extreme weather events and the pollution impacts as well as natural impacts they cause should be considered

and predicted and included as part of the EIS (increased wind throw, increased erosion, more blowouts during construction due to heavy rains, more runoff and extreme peak flows etc.).

Permanent and temporary loss and impact to riparian vegetation and benthic communities must be considered in EIS

Pipeline construction also results in the loss of riparian vegetation. For each pipeline construction technique, there is a resulting loss of foliage associated with clearing the stream banks. This reduction in foliage increases stream temperature and reduces its suitability for fish incubation, rearing, foraging and escape habitat. Benthic macroinvertebrate populations are also reduced with loss of riparian vegetation, as diverse benthic populations disappear; literature has shown decreased denitrification and cycling of nutrients and algae, and reduction of water quality impacts farther downstream that can impact water supplies and habitat downstream. Both permanent and temporary riparian impacts need to be considered in the EIS since in many cases vegetation along streambanks in way of trees will not be allowed to regrow along the pipeline path.

The loss of vegetation also makes the stream more susceptible to erosion events, as the natural barrier along the stream bank has been removed. 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 quality. Furthermore, deposited sediment has the potential to fill in stream pool and floodplain areas and reduce stream depth downstream of the construction area. In turn this can exacerbate future flooding impacts.

Forest fragmentation, habitat loss and loss of carbon sequestration with loss and impact of soils and forests must be considered in EIS

Forest fragmentation and habitat loss is a serious and inevitable consequence of increased pipeline construction activity. The right of way for a pipeline construction zone ranges from 25-200 feet, on average, the right of way for the Leidy SE Line project extends no less than 100 feet, for example. 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." In addition, the right of way will need to be maintained and kept clear throughout the lifetime of the pipeline, which can be up to 80 years. Furthermore, scientific literature shows edge effects and impacts 300 feet from the pipeline ROW in the adjacent forest on either side of the ROW – this calculation and disturbance must be part of the EIS.

Additional sedimentation and erosion impacts across steep slopes

The AS would cut across mountains and steep slopes. Past pipeline projects in the steep northeast have experienced more sediment blowouts and issues with erosion on these steep slopes, especially when the cuts eliminate the forest on these steep slopes. Even with BMPS in place, these steep slopes are irreparably changed and erosion even years later has been noted on old and relatively new pipeline projects alike. For example, cutting across Second Mountain in Schuylkill County with its soils that are prone to erosion, is only an accident waiting to happen and with increased storms due to climate change, which is exacerbated from methane gas, more downpours will likely lead to increased erosion issues permanently along the ROW. Continued erosion and rawbanks longterm due to only herbaceous vegetative growth along a pipeline path leads to opportunistic invasive plant species often colonizing these disturbed areas.

Flow velocity & potential heat impacts from pipelines on adjacent water and land
FERC should require that Williams/Transco submit data detailing generally what the maximum safe operation limits are for flow velocity on its system, what the flow velocity is within the current system, and what the flow velocity will be in its proposed Project for each of the loops. During the winter months along a similar pipeline project in the Northeast, DRN observed multiple areas where snow was melted or shallower along the pipeline route. What impacts might be occuring to the soil and waters from these pipelines that appear to possibly heat up the land and surrounding waterbodies.

Invasive species & herbicide and mowing maintenance impacts must be considered in EIS
The clearing of forest for pipelines often results in the introduction of exotic invasive species (such as Japanese knotweed, mile-a-minute weed, Japanese stiltgrass, purple loosestrife, phragmites and many other invasive plants observed along existing pipeline corridors), native wildlife species decline, and the creation of microclimates that degrade forest health through sunscald and wind-throw occur. These linear pipeline projects are particularly effective at spreading these introduced plant species along the linear corridor, moving invasives far along the pipeline route and impacting more natural areas along the corridor. The impact that continued maintenance, if done, to control these invasive plant species, often using toxic herbicides, must also be considered in the EIS. If mowing is needed over time along the new green spring ROW, these periodic manmade impacts of disturbing the cycle of herbaceous growth and things like butterfly larvae or E&S insect and other species feeding or foraging on that growth in the ROW must also be considered.

Habitat fragmentation also deprives interior forest species of the shade, humidity, and tree canopy protection that well developed deep forest environments provide. Furthermore, oftentimes the land being cleared has been identified as soils that have poor re-vegetation growth, thus resulting in land being "temporarily cleared" for construction activity that is then unable to be restored to its previous condition. There is no such thing as a temporary impact as the pipeline company often claims with their temporary work spaces.

Wetland alterations and impacts must be considered in the EIS
The practice of indiscriminant clearing of vegetation and construction techniques commonly used in and around wetlands through which pipelines pass result in permanent alteration in the kind and quality of wetland habitat. Forested wetlands are often converted to emergent wetlands and as such result in a significantly altered habitat condition that exists throughout the operational life of the pipeline. DRN attaches a report documenting the adverse impacts associated with the conversion of forested to emergent wetlands conducted by Schmidt Associates.

Soil compaction
Even with BMPs utilized in typical pipeline construction, there is evidence that indicates permanent soil compaction, even in work spaces pipeline companies claim are only temporary. The soil profile, especially in regions like Schuylkill County where the topsoil is limited, it is a tremendous impact to cut into these soils. Much of the Schuylkill County farming community, for example, utilize no till alternatives because of the soil organisms and erosive nature of these soils. Yet the pipeline company would likely proposed cuts throughout the pipeline length (versus HDD). For example, soil compaction surveys conducted by Ameliora Associates along a pipeline constructed in the northeast in 2010, indicated soil compaction as great as that of a compacted earthen dam, in areas that the pipeline company claimed were simply temporary work spaces. This compaction leads to problems with revegetation and plant growth – for both agricultural

crops and native vegetation, lesser carbon sequestration in the soil, less nutrient uptake, and irreparable damage to the soil. In addition, the soil is made up of complex organisms and symbiotic organisms and soil relationships that are disrupted when earth disturbance like that of pipeline cuts occurs. The leaf litter which is an important part of the living soil ecosystem in forested areas where the pipeline would cut, is disrupted during pipeline construction. This disruption impacts millions of organisms. For example, the number of animals, protozoa, and bacteria that live in a square meter of ground are in the millions. This web of soil life can be imagined in a pyramid where bacteria and actinomycetes are at the base of the food soil web and number in the billions, followed by millions of protozoa, nematodes, mites, springtails, rotifers and tardigrades, insects, myriapods, spiders, diplurans, potworms and earthworms, snails and slugs and finally vertebrates at the top of the soil web (Nardi, Life in the Soil, 2007). All of these organisms rely on one another to thrive and there is a coexistence and balance in soils that would be disrupted upon earth disturbance by pipeline construction. This permanent impact to the soil profile, organisms, and compaction must be part of the EIS analysis. Even still, though pipeline companies are supposed to stock pile top soil in agricultural lands, no such requirement is in effect for forested areas, where even more damage is done by pipeline cuts to the forest soil (see memo related to soil compaction in temporary work spaces).

Impacts to E&S species, loss of recreation with lesser interior bird and fish populations must be considered

The EIS must also consider impacts to endangered and threatened species that this linear project and associated projects would cause. Attached is a report commissioned by the Delaware Riverkeeper Network discussing impacts of the kinds of land disturbance associated with pipelines on threatened and endangered bat species. The U.S. Fish and Wildlife Service, in its June 20, 2013 comment, expressed concerns regarding the impact of this project on already stressed bat populations. Bats are an important part of the ecosystem and additional harms to their already diminished populations is vital. Bats also provide a service to agriculture by their natural insect control. Reducing the width of the project Right of Way as well as avoiding at all costs interfering with bat habitat needs to be a priority consideration for this project.

A resident of the region testified at the Lebanon FERC scoping meeting and noted an endangered butterfly species that lives along the path of the AS project. Anecdotal evidence from naturalists and citizen monitoring program needs to be considered during the EIS. Bog turtle are also likely to be impacted and must be considered. Because this greenspring pipeline project would cut through areas with limited industrial activity that are characterized as rural forested landscapes, it is critical that FERC and the agencies investigate other endangered and threatened species that may reside in the region. For example, Schuylkill County has a 2006 *Open Space and Greenway Plan* and a 2009 *Natural Areas Inventory of Schuylkill County, Pennsylvania*. It is critical that FERC investigate the potential for E&S species at the state and federal level, and open space and easements along the path of the pipeline.

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 water body. The capacity of a water system to recover from a multitude of impacts may be exceeded with the detrimental effects of crossing construction becoming permanent. Recurrent stresses on fish, such as those originating from elevated suspended sediment concentrations, will have negative effects on fish health, survival and reproduction. All of these impacts require review and consideration as part of AS NEPA review.

Forest fragmentation from pipelines and associated gas pad development also impacts forest interior bird species that are in decline and in some cases endangered or threatened. In turn as bird species decline, fewer ornithologists will come to the region to explore the region's birds. The same would be true of Class A wild trout streams and trophy fishing streams along the pipeline path that would be impacted negatively. Furthermore, hikers and outdoor nature lovers visitors to these rural areas lessen as drilling impacts expand and people seek other places away from the region to recreate where gas infrastructure is not prevalent. The recreational impact to a state like PA that historically thrives on outdoor recreation needs to be part of the EIS. This sustainable economic loss of recreation from birders, fisherman, hikers, backpackers, naturalists must be included in the EIS.

Historic and active coal mining impacts

Residents of Schuylkill County have also noted that a high pressure explosive methane gas pipeline through geology of the region that involves underground boreholes, historic room and pillar deep anthracite mining, and strip mining must be considered as part of the EIS. To cite an explosive pipeline through regions impacted by coal extraction could be an accident waiting to happen. Centralia is in eastern Schuylkill County and has been burning underground for decades.

Consequences of shale gas extraction must be considered in any NEPA review of AS

Induced shale gas extraction and development activities, including drilling and fracking, is a related, connected, and foreseeable outcome of the proposed AS facility given that the pipeline is intended to secure and support increased shale gas development. As such, NEPA requires consideration of the environmental and community impacts of shale gas development that will result in order to supply the AS pipeline and its other related supply facilities like Cove Point.

Shale gas development is an extraordinarily land and water-intensive process that converts agricultural, forest, and range lands to industrial uses, consumes millions of gallons of water per well, and generates huge quantities of hazardous wastes. All aspects of cumulative harm and direct and indirect impacts related to the full life cycle of gas drilling need to be considered in the EIS. Some (but not all) of the major water quality impacts shale gas development causes include:

Casing and cementing failures – Leaking gas wells & engineering problems over time

Failures in the integrity of well casing and cementing occur regularly, either because of faulty construction or because of degradation over time, opening potential pathways for contaminants to reach shallow aquifers. It is also scientifically demonstrated that fracking can create fissures that extend above the targeted horizontal shale layer and link with naturally occurring fissures or abandoned wellbores, allowing methane, fracking fluids, and produced wastewaters/flowback to reach shallow aquifers. For example, Schlumberger, one of the world's largest fracking companies, published an article in 2003 showing about 5% of wells leaked immediately, 50% leaked after 15 years and 60% leak after 30 years. More recent data from PADEP substantiate these leaks with drilling in PA which would be associated with the AS. DEP data indicate a 6% structural integrity failure rate observed for wells drilled in 2010, 7.1% leakage rate for observed wells drilled in 2011, and 8.9% leakage rate observed for wells drilled in 2012. A 2014 analysis of more than 75,000 compliance reports for more than 41,000 wells in PA found that newer wells have higher leakage rates and that unconventional shale gas wells leak more than conventional wells drilled within the same period. Industry has no solution for rectifying well casing leaking (Compendium by

Concerned Health Professionals of NY, July 10, 2014). In addition to these known leak rates, well blowouts, spills and cases of surface water contamination has steadily grown.

Hazardous waste disposal

Shale gas extraction uses and produces numerous toxic substances that are not governed by uniform national standards for treatment and disposal. Drilling muds and fracturing fluids contain a laundry list of toxic ingredients, while produced waters and drill cuttings bring to the surface naturally occurring hazards such as highly carcinogenic BTEX chemicals (benzene, toluene, ethylbenzene, and xylene) as well as brines, radioactive materials, arsenic, mercury, and hydrogen sulfide. Most of these wastes are exempt from regulation under Subtitle C of the Resource Conservation and Recovery Act governing the generation, transportation, treatment, storage, and disposal of hazardous wastes. Similarly, under the Comprehensive Environmental Response, Compensation, and Liability Act, petroleum and natural gas (including liquefied natural gas) are excluded from regulation as hazardous substances. These wastes pose water contamination and health hazard risks whether they are buried in pits, applied to land, injected into underground wells, sprayed into the air, spilled, leaked, or intentionally dumped. In addition the diesel truck trips to dispose of this water and move it around must be considered in the EIS.

Wastewater treatment and disposal

Flowback fluids and produced water that result from HVHF and drilling contain all of the chemicals released during the fracturing process. Wastewater pollutants include everything from lead, arsenic, benzene, diesel fuel, and high levels of total dissolved solids to naturally occurring radioactive materials such as uranium and radium. The Marcellus shale has been found to be more radioactive than other shale formations. Measurements of radium in fracking wastewater in NY and PA have been as high as 3,600 times the US EPS's limit for drinking water. . Ground and water contamination may result from spills, leaks, or improper disposal. Common disposal methods for the wastewater include underground injection and the transport of flowback to wastewater treatment facilities. Underground injection of fracking waste has been associated with induced seismicity. With regards to the use of wastewater treatment facilities for treatment and disposal, most commercial and municipal wastewater treatment facilities are ill-equipped to handle fracking waste. Such facilities are unable to remove naturally occurring radioactive material from the waste stream and the high levels of total dissolved solids present may overwhelm a plant's treatment capacity. Once released into surface waters following insufficient treatment, the wastewater may subsequently overwhelm the dilution-capacity of rivers in regions undergoing intensive shale gas development. In addition the disposal of drill cuttings that are radioactive are another impact. Unsafe levels of radon and its decay products in Marcellus shale natural gas may also contaminate pipelines and compressor stations, as well as pose risks to end users when gas travels through pipelines into people's homes for use. Waste disposal continues to be a major unresolved hazard with unconventional gas drilling.

Water consumption & earthquakes

The proliferation of shale gas development has the potential to degrade water systems due to the massive volumes of water consumed. It is estimated that one fracked well may use 5-7 million gallons of water on average. To the extent that fracking fluids remain underground or are disposed of in underground injection wells, much of the freshwater used for fracking is permanently removed from the hydrological cycle. While some improvements have been made in developing wastewater reuse systems, eventually the pollutants in the fracking fluid reach such extreme concentrations that the fluid becomes

unusable and must be disposed of. At the same time, this injection of heavy water into the geology for disposal or fracking can cause earthquake swarms as faults slip and become lubricated which may in its own right, cause more damage to nearby wells – in turn causing more leaking to air and water. AS could lead to gas drilling in NY, where DEC has raised large concerns of earthquake and seismic activity impacting NYC's aqueduct dependent drinking water supply and watershed infrastructure.

Accidents, negligence, and illegal actions

Accidents resulting from negligent construction methods and operations are inevitable. In 2011 alone, the Pennsylvania Department of Environmental Protection issued more than a thousand notices of violation to natural gas operators within the Marcellus Shale region. This represents a 400% increase in reported violations as compared to 2008 – thus emphasizing that activities which encourage increased drilling also result in increased harm. These accidents cover a wide spectrum of violations, including surface spills, blowouts, improper casing construction, erosion and sediment control failures, faulty pollution prevention, failures in site restoration, improper waste management, and wastewater impoundment construction failures. One well blowout is estimated to occur for every thousand wells drilled; however, the severe consequences of a blowout make this ostensibly small number significant.

In April 2011, for example, a natural gas well operated by Chesapeake went out of control for roughly twelve straight hours, spewing more than 10,000 gallons of chemically laced fuel into the local environment, which included a pasture and creek. Dave Fehling, "When Wells Blow Out In Pennsylvania, Texans Step In," Jan. 5, 2012, http://stateimpact.npr.org/texas/2012/01/05/when-wells-blow-out-inpennsylvania-texans-step-in/.

Land disturbance

Shale gas development consumes not only vast quantities of water but also acres of land for well pads, pipelines, and access roads. In the forested and agricultural lands overlaying the Marcellus Shale, this massive industrialization will cause widespread impacts to surface water quality from deforestation, stormwater runoff, and erosion and sedimentation.

Forests play an essential role in water purification. The scientific literature clearly establishes the link between percent forest cover and water quality; for example, reductions in forest cover are directly correlated with negative changes in water chemistry, such as increased levels of nitrogen, phosphorus, sodium, chlorides, and sulfates as well as reduced levels of macroinvertebrate diversity. Reducing forest cover decreases areas available for aquifer recharge, increases erosion, stormwater runoff, and flooding, and adversely affects aquatic habitats. Already in Pennsylvania, researchers have correlated areas of high natural gas well density with decreased water quality, as indicated by lower macroinvertebrate density and higher levels of specific conductivity and total dissolved solids.

Both deforestation and shale gas infrastructure construction and operation will, in turn, lead to greatly increased levels of erosion, sedimentation, and stormwater runoff affecting surface water quality. Excess sedimentation is associated with a number of detrimental effects on water quality, stream orphology, and aquatic life, and has been identified by the EPA as one of the primary threats to US surface waters.

Shale gas well sites are like traditional construction sites in terms of stormwater runoff and sediment

discharge levels. A 2005 EPA study concluded that "gas well sites have the potential to negatively impact the aquatic environment due to site activities that result in increased sedimentation rates." In Pennsylvania, the Nature Conservancy has estimated that nearly two-thirds of well pads targeting the Marcellus Shale will be developed in forested areas, necessitating the clearing of 38,000 to 90,000 acres. An additional 60,000 to 150,000 acres of forest area will be lost to pipeline construction and right-of-way maintenance.

Compressor stations along the pipelines, which occupy an average of five acres each, are likely to number in the hundreds. In New York, deforestation will occur on a similar scale, with losses in forest cover of up to 16%.

Heavy truck traffic on rural roads, especially unpaved roads, that were not built to withstand hundreds or thousands of truck trips also leads to significant erosion and sedimentation problems. Thousands of truck trips with each vehicle weighing up to 10 tons, may be required to construct and operate a single well. Ditches along rural roads are the primary pathways for the conveyance of polluted runoff bearing sediments and nutrients to streams, and increase runoff volume and energy as well, contributing to flooding. In addition, access roads constructed or modified to enter gas exploration or extraction facilities contribute significantly to sedimentation and surface water quality degradation.

Pipeline construction and right-of-way maintenance account for a significant proportion of shale gas extraction's land use impacts. Pipelines also create significant erosion and sedimentation problems during construction as well as over the decades-long maintenance of cleared rights-of-way. In joining well pads to transmission infrastructure, a single gathering line may cross numerous streams and rivers, especially in states such as Pennsylvania with a high density of stream mileage per unit of land. Stream and wetland pipeline crossings cause erosion and sedimentation whether implemented through dry ditch or wet ditch crossings. Though erosion and sediment control permits may be required for stream crossings—indeed, in Pennsylvania they are the only permits necessary for gathering line construction—in practice, permit requirements are routinely violated. Both dry and wet ditch crossings necessitate the clearing of area stream banks. Because riparian vegetation functions as a natural barrier along the stream edge, both removing sediment and other pollutants from surface runoff and stabilizing stream banks, its clearing necessarily increases a stream's susceptibility to erosion events. Cumulatively, the construction of numerous crossings across a single watercourse may significantly degrade the quality and flow rate of the water body. Erosion and sedimentation problems are often exacerbated by the staging of construction, during which soils are exposed for long periods and over long distances by clearing, grading, and trench cutting before final pipeline installation and revegetation.

Health impacts

Contamination by drilling of surface waters that serve to provide drinking water to communities is also a concern. In September, 2011, concerned about the implementation of drilling and the discharge of drilling wastewater in the watersheds that serve drinking water to New York City and other communities, scientists write Governor Cuomo expressing their concern that there does not exist adequate knowledge to conclude that filtering by municipal drinking water filtration systems "would remove all, or even most, of the hazardous substances found in flow-back fluids from hydraulic fracturing. Potential contaminants of concern known to be in some flow-back fluids include benzene and other volatile aromatic hydrocarbons, surfactants and organic biocides, barium and other toxic metals, and soluble radioactive compounds. containing thorium, radium and uranium. We believe, however, the best available science suggests that

some of these substances would pass through the typical municipal filtration system." While there is genuine concern about a lack of investigation and data into the human and livestock health impacts of gas drilling, the body of research and knowledge that is documenting the human and animal health harms of gas drilling is growing. For example: "Documentation of cases in six states strongly implicates exposure to gas drilling operations in serious health effects on humans, companion animals, livestock, horses, and wildlife." Though the healthy community is behind on gas impacts, the following symptoms have been documented in families whose households are near fracking operations: sinus respiratory problems, changes in behavior and mood/energy, neurological issues, muscle and joint pain, digestive and stomach issues, problems with ear, nose and throat, skin rashes and reactions, and vision impacts. DRN is attaching the Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking by the Concerned Health Professionals of NY (July 10, 2014).

Agricultural impacts

Studies and case reports indicate instances of deaths, neurological disorders, aborted pregnancies, and still births in cattle and goats associated with livestock exposed to drilling wastewater. Soil quality, if contaminated or compacted by drilling or infrastructure can reduce crop yield. Additionally, farmers have expressed concern that nearby fracking has affected their business as perception about healthy food supplies dwindles in areas where this heavy industry resides. It is also imperative that the EIS examine, for example, changes in dairy operations as dairy farmers sell off their property and leave the state, selling off their property (Penn State study). At the same time, there are organic CSA's and sustainable agriculture small businesses that are thriving near and along the proposed pipeline. Impacts to these family sustainable farmers and traditional corn, soy and dairy farmers need to be considered.

Sacrificial zones

Pennsylvania known for its natural lands including outdoor recreation, Class A trout streams, and rural character and the impacts this pipeline would cause must be addressed in the EIS. Studies have shown that as unconventional gas drilling has occurred in PA, those who have the means to leave the state, creating essentially a vacuum, to find safer homes to raise their families away from gas drilling should be considered as part of the EIS. Do we really want those who can leave the state to flee to areas to places like NY where a no drilling policy has been in place? At the same time environmental justice issues do apply to rural regions where families do not have the opportunity or ability to move away from such pollution sources, exposing their families to pollution from the industry.

Emissions

Because the construction of AS will encourage further gas production, NEPA review must account for emissions and air pollution from wells, compressors, pipelines, pneumatic devices, dehydrators, storage tanks, pits and ponds, natural gas processing plants, and trucks and construction equipment. Major air pollutants of concern from these operations include methane (CH4), volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur dioxide (SO2), hydrogen sulfide (H2S), and particulate matter (PM10 and PM2.5). Oil and natural gas operations also emit listed hazardous air pollutants (HAPs) in significant quantities, and so contribute to cancer risks and other acute public health problems. The oil and gas industry is the single largest source of methane emissions in the US, accounting for nearly 40 % of national methane emissions. All these direct, indirect, and cumulative impacts are relevant considerations for FERC to examine under the required NEPA analysis.

Threats and exacerbation of climate change

Methane is a heat trapping gas that is at least 17 times more heat trapping than CO_2. Therefore release of methane into the air is only excaserbating climate change impacts. EPA has indicated that leaking even at traditional wells is much greater than they originally anticipated. Unconventional rates and leakage or greater (see section above).

Conclusion

Authorizing AS will mandate increased drilling, fracking, LNG export facilities, pipelines and other infrastructure development in order to serve its needs. AS is also a greenspring pipeline project which will create brand new impacts along this new ROW if permitted. As a result, the AS will be foreseeably and directly responsible for creating and exacerbating these types of environmental impacts. Furthermore, a number of existing pipeline projects and LNG facilities are inextricably intertwined with the development of AS. Each one of the environmental impacts described above results in harm to the environment that is significant in character. Because the AS proposal is directly or indirectly responsible for such impacts the Commission must complete a thorough EIS that is cumulative and thorough. If FERC does a thorough EIS and weighing alternatives on clean energy, DRN believes there is no possibility the AS pipeline and its related infrastructure could be given approval to be built due to its extensive harm. Furthermore, alternative energy truly based on sustainable and renewable sources would be the path forward that FERC would have to scientifically agree is the prudent and sensible path forward.

Respectfully submitted,

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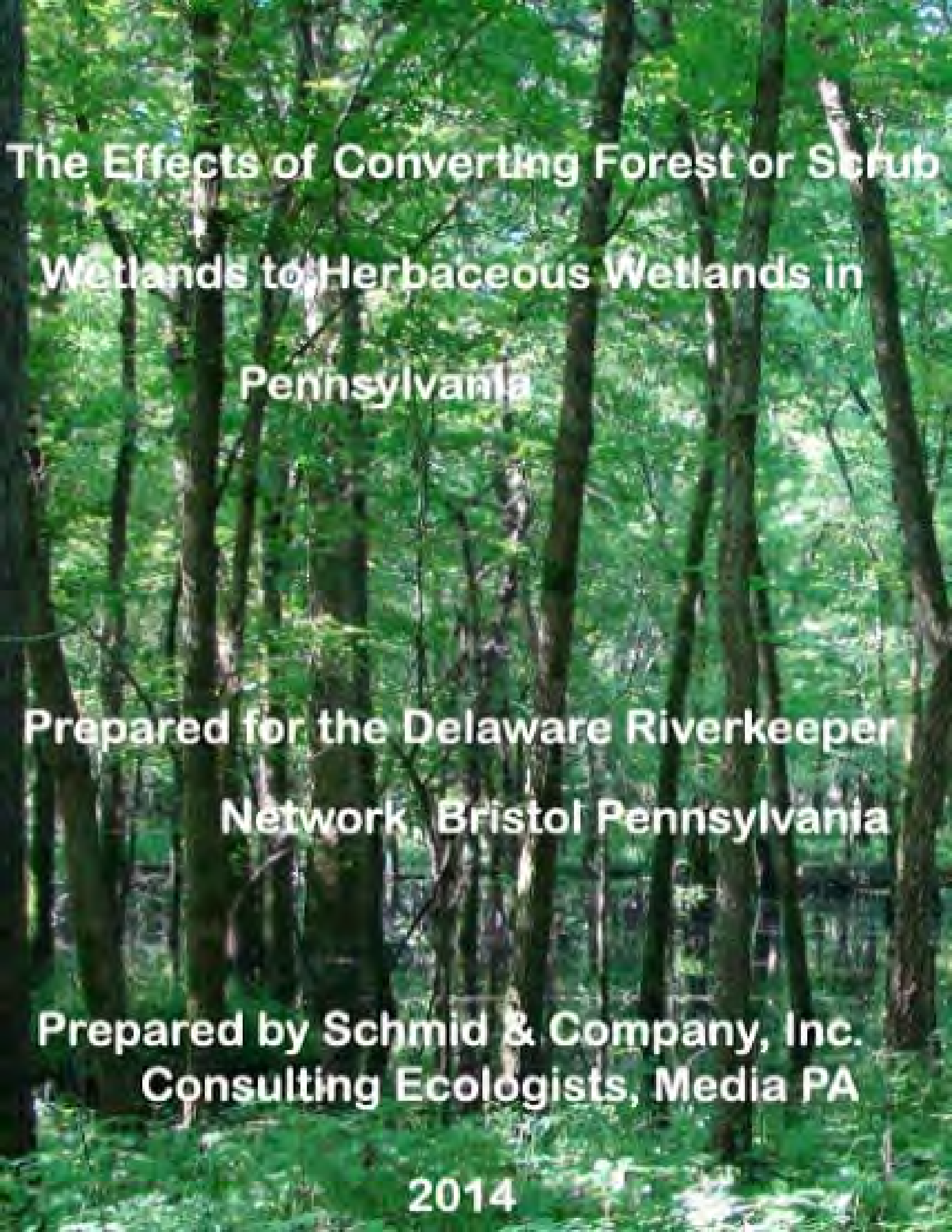

The Effects of Converting Forest or Scrub Wetlands to Herbaceous Wetlands in Pennsylvania

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2014

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The Effects of Converting Forest or Scrub Wetlands to Herbaceous Wetlands in Pennsylvania

Wetlands are tracts of land characterized by the recurrent and prolonged presence of surface water and/or near-surface groundwater. Their vegetation, wildlife, and soil properties are greatly influenced by wetness, that is, by their hydrology. Wetness has a profound effect on the biogeochemical reactions that occur in the top foot of wetland soil, allowing bacteria to render such soils anaerobic (oxygen-free) and thereby affecting the chemistry of the soil particles as observed in soil color and organic matter, determining the kinds of microorganisms present, selecting the kinds of rooted plants able to survive and compete, and in turn affecting the quality of habitat for animals including humans. Like streams, ponds, lakes, rivers, and oceans, wetlands today are deemed to be bodies of surface water, peculiar places transitional between (1) permanent open waters and (2) dry lands wet only during precipitation events. Some wetlands are associated with areas where surface waters and groundwater interconnect.

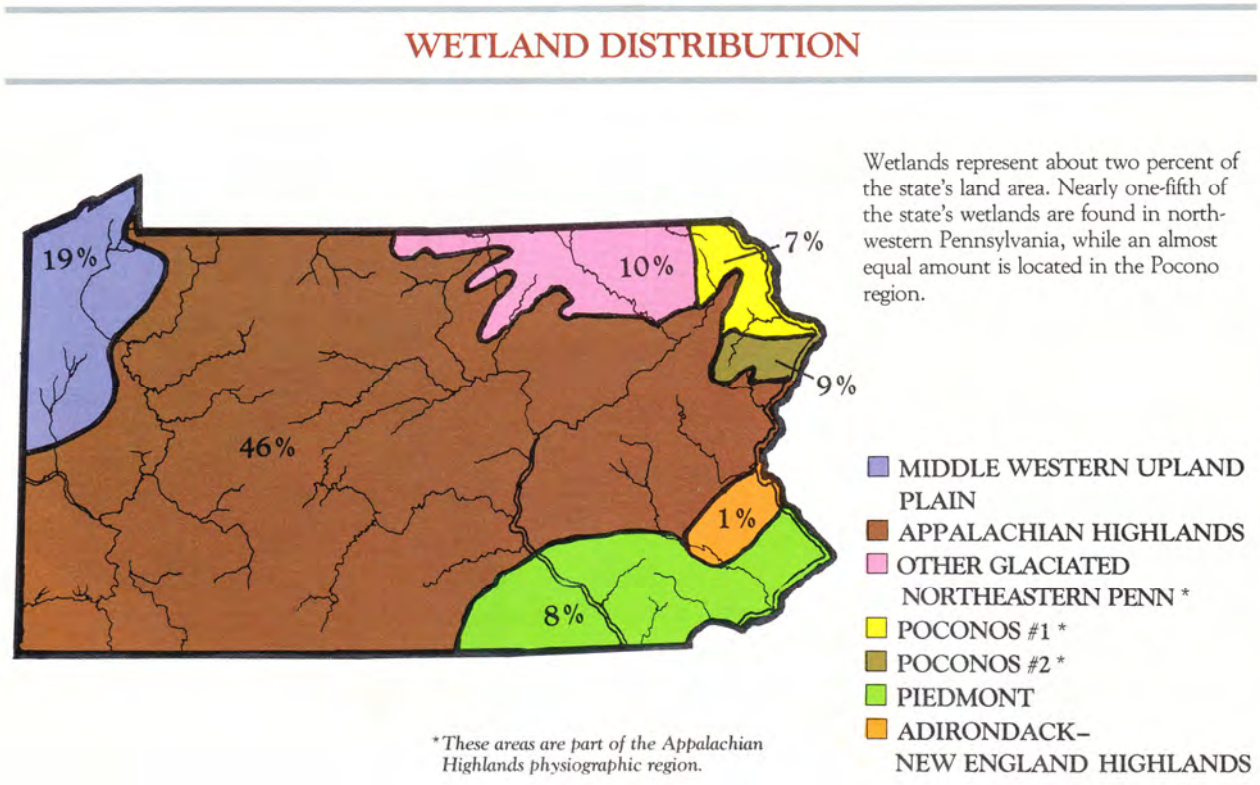
For many years wetlands were regarded as wastelands, and public policy encouraged their physical conversion to accommodate more highly valued land uses of many kinds (farms, cities, roads, residential and commercial development). In response, millions of acres of wetlands were destroyed across the United States, including more than half of Pennsylvania's wetlands (more than 600,000 acres). Not until the latter half of the twentieth century were the environmental and societal values of suddenly scarce wetlands broadly appreciated and subjected to legal protection against unnecessary alteration in the United States (Schmid 2000). Today most construction activities in wetlands are regulated by public agencies concerned with environmental protection. Regulators at the federal, State, and/or municipal level may be involved in permit review and approval. Most construction activities that would affect wetlands are unlawful, unless previously authorized by permit, but the applicable laws vary greatly from place to place in their scope and stringency.

Wetness (above-ground inundation or in-ground saturation within the uppermost foot of topsoil) for periods of two weeks or more, at least seasonally recurrent, is the primary characteristic that locally distinguishes individual wetlands from non-wetland areas that may display similar climate, exposure (aspect), slope, geology (rock type), soils, and biota (plants, animals, bacteria, fungi). The prolonged presence of surface water at relatively shallow depth (< 6 feet) and the presence of emergent vegetation distinguish wetlands from the deep, open waters of lakes and the flowing channels (some with submerged or floating plants) of streams---other bodies of surface water with which wetlands often are closely associated. Wetlands often occupy a landscape zone transitional between open waters and the seldom-wet uplands found at higher elevations. Along with groundwater, surface streams, rivers, lakes, ponds, and wetlands are regulated Waters of the Commonwealth of Pennsylvania. Many, but not all, of the wetlands and other

surface water bodies in Pennsylvania are also Waters of the United States (USEPA and USACE 2014).

In the large and diverse Commonwealth of Pennsylvania there are many kinds of wetlands. Pennsylvania wetlands in the aggregate occupy a small proportion of the land surface, and are most extensive in formerly glaciated areas such as the plateaus of the northeastern and northwestern counties, as shown below in a National Wetland Inventory drawing (from Tiner 1987). Individual wetlands can range in size from a few square feet to many acres. Wetlands today are recognized as contributing to water quality, wildlife habitat, endangered species protection, and the human landscape far out of proportion to their percentage share of the Pennsylvania land surface, and thus warrant stringent protection from human modifications to the extent practicable. These values increase as human population and population density increase. At the same time, the economic value of property where the destruction of wetlands has been authorized can greatly exceed the cash value of that property in its natural condition. Hence the extent to which public agencies can protect wetland resources often conflicts with the desire of private landowners to alter the property which they own.

Pennsylvania Wetlands Are Geographically Concentrated.



Agencies tasked with implementing the federal Clean Water Act (P.L. 92-500, 86 Stat. 816) and the Pennsylvania Dam Safety and Encroachments Act (32 P.S. 693) and Clean Streams Law (35 P.S. 691), long have defined wetlands as

> Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs and similar areas (25 *Pa. Code* 105.1.)

Accurate wetland identification and delineation depend upon a careful analysis of plants, soils, and hydrology using the best available scientific guidance to apply the official definition in each real situation on the surface of the earth. In the central sections of most wetlands the general public can readily ascertain the distinctive conditions that characterize tree-filled swamps and herb-dominated marshes. Precisely locating the boundaries of a wetland, however, in gently sloping transitional areas where the requisite field indicators gradually drop out, typically requires specialized training in the visual appearance of vegetation, soils, and hydrology as they occur outdoors in all seasons, along with thorough knowledge of relevant agency rules for consistent decisionmaking. The details of scientific knowledge of wetland functions and regulatory adjustments in setting regulatory boundaries and analyzing impacts have changed over recent decades as our understanding of wetlands has increased.

To apply the regulatory definition of wetlands in the field, federal and Pennsylvania regulators (25 *Pa. Code* 105.451) employ the Army Corps of Engineers *Wetland Identification and Delineation Manual* (ERL 1987) in conjunction with its recent regional supplements (for example, USACE 2012) and other technical support documents (including Lichvar *et al*. 2014, Vasilas *et al*. 2010, USACE 2014). These official documents provide the guidance necessary for recognizing the current extent of regulated wetlands under various conditions of season, wetness, and human disturbance, using field indicators of vegetation, soil, and hydrology.

In Pennsylvania the Army Corps of Engineers provides, in response to landowner requests, formal written Jurisdictional Determinations (JDs) that confirm the accurately mapped extent of wetlands and bodies of surface water eligible for regulation at the federal, State, and municipal level on specific tracts of land. Absent the issuance of a valid JD, there is no way for a landowner or the public to ascertain accurately the limits of a regulated wetland. Topographic maps, National Wetland Inventory maps, floodplain maps, soil survey maps, and planning maps of many kinds can provide useful technical information, but do not identify in detail the limits of regulated wetlands (or streams) that need to be considered by the sponsors of construction projects. Consultants typically document sites on behalf of landowners and prepare paperwork for agency review. Careful documentation of wetlands whose proffered boundaries are superimposed onto a land ownership survey is required as part of a request for a

JD, and Corps staff typically inspect each property in the field prior to approving a JD. JDs remain valid for five years, in recognition of the fact that wetland boundaries can change over time as a result of natural changes as well as unregulated human activities nearby. Only the Natural Resources Conservation Service (NRCS), an arm of the US Department of Agriculture, issues permanent wetland identifications for purposes of eligibility for federal programs that support crop production. Such NRCS determinations apply only to farming, not to general construction activities.

Delineated wetlands are best avoided when new construction projects are proposed, and permit applicants are expected to minimize unavoidable impacts insofar as practicable. The JD forms the informational basis for permit calculations and for designing compensatory mitigation to offset agency-approved impacts to the extent practicable.

Recent experience confirms that applicant-proffered wetland boundaries continue to warrant detailed scrutiny by the Army Corps of Engineers and other regulators. In one 2010 mining application in Greene County, National Wetland Inventory maps disclosed 4 wetlands on a 642-acre site. The applicant's consultant submitted a proposed delineation to PADEP showing 10 wetlands. After field inspection by the Corps, the JD drawing of the same tract of land showed 27 wetlands (Schmid & Co., Inc. 2013). In Sullivan County a gas company consultant delineated streams and wetlands in a 50-foot wide right-of-way along some 4,000 feet of unpaved township road. After the adjoining landowners secured Corps JDs, the square footage of regulated streams and wetlands increased to 700% of that flagged for the gas company within the same 4-acre strip of land (Schmid & Co., Inc. 2011b). The Corps field representative commented that significant under-identification of wetlands had occurred at several recent gas well installations where he had been involved with enforcement actions. None of those permittees had secured a Corps JD, and PADEP as usual had approved their permits without questioning the accuracy of information in the applications. It is not possible to overemphasize the necessity for JD applications followed by field-checking by Corps staff of proffered delineations as critical to the identification of wetlands in Pennsylvania prior to permit approval. Unidentified wetlands are not protected at all.

Wetland Permits

Regulated activities in Pennsylvania wetlands and other bodies of water cannot legally be initiated prior to permit approval by the Department of Environmental Protection (PADEP), except for waivered activities (25 *Pa. Code* 105.12) and registered activities that conform to the requirements of pre-approved general permits (25 *Pa. Code* 105.441 *et seq*.). Above established minimum thresholds of impact, regulated activities in federally regulated wetlands and waters also require approval from the Army Corps of Engineers. Except for those areas and

activities excluded from regulation by waiver or authorized via general permits, wetland functions by regulation must be identified by an applicant when permit approval is sought for activities that will encroach upon wetlands and other bodies of water in Pennsylvania (25 *Pa. Code* 105.13). Permit applications for relatively small encroachments may be reviewed only by State agencies; larger or more damaging activities must be considered independently also by federal agencies. Few of the more than 2,500 Pennsylvania municipalities have adopted any ordinances protective of wetlands, but some have included wetlands as among resources to be reviewed at the local level, and their wetlands may be protected over and above what State and federal agencies require. Like PADEP, local agencies generally lack the staff resources to identify jurisdictional boundaries for wetlands.

After wetlands have been identified, permit applicants are expected to avoid impacts, and where unavoidable, to make every practicable effort to minimize impacts when planning their construction projects; PADEP is to review such efforts to avoid and minimize impacts [25 *Pa. Code* 105.14(b)(7)]. Where encroachments are proposed into wetlands, it is the responsibility of the permit applicant to identify onsite conditions in every affected wetland as a basis for ascertaining the probable alteration of functions when analyzing unavoidable adverse impacts and providing appropriate compensatory mitigation (25 *Pa. Code* 105.14, .15, and .18a). Impacts are to be analyzed in an Environmental Assessment (§105.15). The extent and nature of unavoidable impacts become the basis for developing the applicant's proposal for site restoration and compensatory mitigation. The quality of wetland assessment depends on the thoroughness and accuracy of underlying wetland inventory as well as the professional competence of the delineator and agency reviewer. Wetland functions form a principal aspect of the environmental assessment.

PADEP and district offices of the Army Corps of Engineers have adopted a joint permit application (Form 3150-PM-BWEW0036A, March 2013) and related forms that solicit the minimum information needed for agency decisionmaking regarding affected wetlands and other bodies of water on properties where construction is planned that may damage these resources. Public notice is required for individual joint permit applications, but not for waivered activities or for registrations of applicant intent to rely upon general permits. PADEP staffers are charged with reviewing each application to insure its completeness, its accuracy, and the applicant's proposed compliance with applicable regulations. Permit files, application data, and related correspondence are public records and can be examined by persons concerned about wetland protection through the procedures of Pennsylvania's Right to Know Law (Act 3 of 2008) and the federal Freedom of Information Act (5 USC 552 *et seq*.). Upon approval of a PADEP permit, the window for filing appeals to the Pennsylvania Environmental Hearing Board by any aggrieved party remains open for thirty days. Applicants are required to conform to the conditions and limitations set forth in general and individual permits. All recipients of individual permits by regulation are required

to file a statement of compliance with permit requirements within 30 days of work completion and to file final as-built plans within 90 days showing any changes from original plans and specifications (25 *Pa. Code* 105.107).

In Pennsylvania some wetlands are deemed more valuable than others. Exceptional Value wetlands deserve *specia*l protection. Such wetlands exhibit one or more of the following characteristics (25 *Pa. Code* 105.17):

1. Serve as habitat for fauna or flora listed as threatened or endangered under federal or Pennsylvania law.
2. Are hydrologically connected to or located within 0.5 mile of the above and maintain the habitat of the endangered species.
3. Are located in or along the floodplain of the reach of a wild trout stream or waters listed as having Exceptional Value and the floodplain of their tributary streams, or within the corridor of a federal or Pennsylvaia designated Wild or Scenic River.
4. Are located along an existing public or private drinking water supply and maintain the quantity or quality of that surface water or groundwater supply.
5. Are located in State-designated natural or wild areas within State parks or forests, in federally designated Wilderness Areas or National Natural Landmarks.

Wetlands that qualify as having Exceptional Value are defined as surface waters of Exceptional Ecological Significance (25 *Pa. Code* 93.1), and thus (like Pennsylvania streams that have been designated or have attained Exceptional Value uses) are to be treated as Tier 3 Outstanding National Resource Waters in the language of the Clean Water Act of 1972 (as amended, 33 *USC* §1251 *et seq*.; *US Environmental Protection Agency Water Quality Handbook* - Chapter 4: Antidegradation [40 *CFR* 131.12]). These highest-quality resources are to be protected from degradation. Wetlands that do not exhibit any of the above-listed characteristics are deemed “Other” wetlands.

Permits for structures and activities in Exceptional Value wetlands are not to be approved unless PADEP finds that: the dam, water obstruction, or encroachment will not have an adverse impact on the wetland, as determined in accordance with §§ 105.14(b) and 105.15; the project is water dependent, requiring access to, proximity to, or siting within the wetland to fulfill its basic purpose; there is no practicable alternative that would not involve a wetland or that would have less adverse effect on the wetland and not have other significant adverse effects on the environment; the project will not cause or contribute to a violation of an applicable State water quality standard; the project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses; and the applicant replaces the affected wetland in accordance with criteria at § 105.20a [25 *Pa. Code* 105.18a(a)]. Yet Corps Jurisdictional Determinations are not required for Exceptional Value wetlands in Pennsylvania, so these wetlands are equally likely to be overlooked as those lacking exceptional value.

“Other” wetlands also are deemed “a valuable public natural resource” (25 *Pa. Code* 105.17) that is to be protected from significant impacts in similar fashion to

Exceptional Value wetlands. Permits are to be granted to dams, water obstructions, or encroachments affecting Other wetlands only when PADEP finds that: the project will not have a significant adverse impact considering the areal extent of the impacts, values, and functions of the wetlands, the uniqueness of the wetland functions and values in the area or region; comments from environmental agencies have been addressed; adverse impacts on the wetland are to be avoided or reduced to the maximum extent possible; there is no practicable non-wetland impacting alternative; the applicant has convincingly demonstrated that non water-dependent projects have no practicable alternative, overcoming the rebuttable presumption that such alternatives exist; the project will not cause or contribute to violation of an applicable State water quality standard; the project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses; the cumulative effect of this project and other projects will not result in a major impairment of the Commonwealth's wetland resources; and the applicant replaces the affected wetland in accordance with criteria at § 105.20a [25 *Pa. Code* 18a(b)]. On paper, Pennsylvania offers stringent protection to its wetlands.

Wetland Functions

Nine wetland functions are specifically identified in the definitions section of Pennsylvania's Dam Safety and Encroachments regulations (25 *Pa. Code* 25.1). By regulation, these functions are the minimum that require consideration as PADEP evaluates every encroachment permit affecting 1 acre or less of wetlands. Larger wetlands, as well as Exceptional Value wetlands smaller than 1 acre may require more complex assessment of additional functions and values in addition to these [25 *Pa. Code* 105.13(d)(3)]:

Wetland Functions Requiring Analysis in PADEP Permits

1. Serving natural biological functions, including food chain production; general habitat; and nesting, spawning, rearing and resting sites for aquatic or land species.
2. Providing areas for study of the environment or as sanctuaries or refuges.
3. Maintaining natural drainage characteristics, sedimentation patterns, salinity distribution, flushing characteristics, natural water filtration processes, current patterns or other environmental characteristics.
4. Shielding other areas from wave action, erosion, or storm damage.
5. Serving as a storage area for storm and flood waters.
6. Providing a groundwater discharge area that maintains minimum baseflows.
7. Serving as a prime natural recharge area where surface water and groundwater are directly interconnected.
8. Preventing pollution.
9. Providing recreation.

Different wetlands exhibit different combinations of functions. Some mutually exclusive functions (for example, groundwater recharge and groundwater

discharge) can alternate over time within a single wetland. The functions performed by a wetland may vary over seasons and from year to year. The functions that any given wetland is capable of performing result from both the internal characteristics of the wetland itself and the surrounding context in which that wetland exists, including its connection with other natural areas and with watercourses. Corridors for wildlife movement, for example, are important to allow populations of animals to move between areas of wetland habitat, and many streams function as wildlife corridors. Similarly, only a wetland located on the shore of an open water body can shield other areas from wave action. The success of a wetland in performing functions can be affected greatly by past or ongoing human activity. Most wetland functions are disrupted permanently or temporarily by construction activities that impinge upon the wetland vegetation, soils, or hydrology directly. Human activities that increase performance of one function can accompany decreasing performance of other functions by that wetland.

Wetland functions also can be affected by construction outside the wetland itself out to a distance of 1,500 feet or more (Houlahan *et al*. 2006). For example, wildlife that breed in wetlands, such as reptiles and amphibians including frogs and salamanders, normally range into the adjoining uplands for distances of many hundreds of feet in eastern North America during the course of an annual cycle. If the adjacent lands are deforested or paved, or the wetland isolated by an intervening road or fence, the wetland habitat can be rendered useless to such creatures. By way of further example, altering the light and wind by removing the surrounding forest can cause a major change in the plants and animals that can survive in a wetland. Surface disturbances outside a wetland also can have major impact on the hydrology of the wetland, profoundly altering its ecosystem by draining or flooding it.

There is no State-regulated wetland buffer in Pennsylvania, such as exists in New Jersey or New York. Those States have expressed concern for the variable boundaries of wetlands that result from differing weather conditions year to year. They wisely recognize that the associated transitional areas adjacent to wetlands comprise essential parts of the functioning ecosystem of each wetland. Hence they long have considered the preservation of ecosystems adjacent to a wetland to be an essential part of protecting that wetland's functions and values. The absence of regulated buffers around wetlands in Pennsylvania renders its wetlands at risk of unavoidable degradation, especially in areas of concentrated human populations. A few Pennsylvania municipalities have recognized or sought to remedy this environmental risk through local ordinances that provide for maintenance of some amount of undeveloped protective buffer outside the wetland.

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Wetland Classification

The functions and values of a wetland differ according to the placement of the wetland in the landscape and the manner in which it gains its wetness.

Functional analysis logically addresses different classes of wetlands differently when addressing their potential for damage or rehabilitation. Wetlands and shallow water bodies are usefully categorized at the most basic level by general hydrogeomorphic system. Across most of the Pennsylvania landscape, wetlands and small ponds are assigned to the Palustrine (P) system, which is distinguished from tidal estuarine and marine classes, lakes, and large rivers. Wetlands along the boundaries of water bodies are assigned to the Riverine (R) or Lacustrine (L) systems, although many floodplain wetlands are labeled as Palustrine. Marine (M) and Estuarine (E) classes are of limited extent in Pennsylvania.

The following table identifies the most recent hydrogeomorphic classifications under development by the PADEP (draft Technical Guidance Document 310-2137-002, 7 March 2014, p. 27). The classification is significant as it affects the functional analysis of all water bodies including wetlands.

Mid-Atlantic HGM Wetland Classification:

- Classes
  - Subclasses
    - Modifiers
- Marine
  - subtidal
  - intertidal
- Estuarine
  - subtidal
  - lunar intertidal
  - wind intertidal
  - impounded
- Riverine
  - lower perennial
  - floodplain complex
  - upper perennial
  - headwater complex
  - intermittent
    - beaver impounded
    - human impounded
- Lacustrine (fringe)
  - permanently flooded
  - semipermanently flooded
  - intermittently flooded
  - artificially flooded
- Palustrine
  - Flat
    - Flat mineral soil
    - Flat organic soil
  - Slope
    - Stratigraphic
    - Topographic
      - mineral soil
      - organic soil
  - Depression
    - perennial
    - seasonal
    - temporary
      - human impounded
      - human excavated
      - beaver impounded

PADEP goes on to offer additional detail on the principal kinds of wetlands in Pennsylvania classed by location associated with hydrology that require consideration during functional assessments. The modifiers give an idea of the variability of the basic types (draft Technical Guidance Document 310-2137-002, 7 March 2014, p. 24-25). Once these distinctions have been formally adopted by PADEP for consideration in each permit application, the precision and quality of data provided by applicants' consultants should improve, along with the quality of impact analysis.

Pennsylvania Hydrogeomorphic Wetland Classification Key.

1.	Wetland found along tidal fringe of a marine ecosystem (ocean, beach, rocky shore)	2
1.	Wetland not associated with marine ecosystem	3
2.	Continuously submerged littoral zone	**Marine subtidal** (MF1)
2.	Alternately flooded and exposed to air	**Marine intertidal** (MF2)
3.	Wetland associated with shallow estuarine ecosystem (Mixture of saline and freshwater)	4
3.	Wetland not associated with shallow estuarine ecosystem	7
4.	Wetland not impounded	5
4.	Wetland impounded	**Estuarine impounded** (EFh)
5.	Wetland continuously submerged	**Estuarine subtidal** (EF1)
5.	Wetland alternately flooded and exposed to air	6
6.	Wetland regularly or irregularly flooded by semidiurnal, storm, or spring tides	**Estuarine lunar intertidal** (EF2l)
6.	Wetland flooding induced by wind	**Estuarine wind intertidal** (EF2w)
7.	Wetland associated with freshwater stream or river	8
7.	Wetland not associated with freshwater stream or river	11
8.	Wetland associated with permanent flowing water from surface sources	9
8.	Wetland dominated by ground water or intermittent flows	10
9.	Wetland associated with low gradient tidal creek (see Estuarine types 3)	
9.	Wetland associated with low gradient and low velocities, within a well-developed floodplain (typically >3rd order)	**Riverine lower perennial** (R2)
9.	Wetland part of a mosaic dominated by floodplain features (former channels, depressions) that may include slope wetlands supported by ground water (see Slope 17)	**Riverine floodplain complex** (R2c)
9.	Wetland associated with high gradient and high velocities with relatively straight channel, with or without a floodplain (typically 1st - 3rd order)	**Riverine upper perennial** (R3)
10.	Wetland part of a mosaic of small streams, depressions, and slope wetlands generally supported by ground water	**Riverine headwater complex** (R3c)
10.	Wetland associated with intermittent hydroperiod	**Riverine intermittent** (R4)

Note:	For any riverine type that is impounded, distinguish between:	
	Wetland impounded by beaver activity	**Riverine...beaver impounded** (R...b)
	Wetland impounded by human activity	**Riverine...human impounded** (R...h)
11.	Wetland fringing on a lake or reservoir	**12**
11.	Wetland not fringing on lake or reservoir	**14**
12.	Wetland inundation controlled by relatively natural hydroperiod	**13**
13.	Wetland inundation is permanent with minor fluctuations (year round)	**Lacustrine permanently flooded** (LFH)
13.	Wetland inundation is semipermanent (growing season)	**Lacustrine semipermanently flooded** (LFF)
13.	Wetland inundation is intermittent (substrate exposed often)	**Lacustrine intermittently flooded** (LFJ)
12.	Wetland inundation controlled by dam releases	**Lacustrine artificially flooded** (LFK)
14.	Wetland water source dominated by precipitation and vertical fluctuations of the water table due to low topographic relief	**15**
14.	Wetland differs from above	**16**
15.	Wetland substrate is primarily of mineral origin	**Flat mineral soil** (FLn)
15.	Wetland substrate is primarily of organic origin	**Flat organic soil** (FLg)
16.	Wetland water source is primarily ground water and has unidirectional and horizontal flows	**17**
16.	Wetland forms a depression	**18**
17.	Water source for wetland derived from structural geologic discontinuities resulting in discharge of groundwater from distinct point(s) on slope	**Stratigraphic slope** (SLs)
17.	Water source for wetland accumulates at toe-of-slope before discharging	**Topographic slope** (SLt)
Note:	For any slope type, distinguish between: Wetland substrate is primarily of mineral origin	**...slope mineral soil** (SL...n)
	Wetland substrate is primarily of organic origin	**...slope organic soil** (SL...g)
18.	Wetland with frequent surface connections conveying channelized flow	**Depression perennial** (DFH)
18.	Wetland with infrequent surface water connections conveying channelized flow	**Depression seasonal** (DFC)
18.	Wetland with no surface outlet, often perched above water table	**Depression temporary** (DFA)
Note:	For any depression type that is impounded or excavated distinguish between:	
	Wetland is impounded by human activities	**Depression...human impounded** (DPh)
	Wetland is excavated by human activities	**Depression...human excavated** (DPx)
	Wetland is impounded by beaver activities	**Depression...beaver impounded** (DPb)

Another of the basic classifications of wetlands derived from their appearance and germane to assessing their functions is their vegetation type. The descriptive framework for vegetation structure was devised by the US Fish and Wildlife Service (Cowardin *et al*. 1979) and is used for small-scale mapping by the National Wetlands Inventory. Vegetation and hydrogeomorphic location are combined to identify the principal habitat types identified by PADEP in Pennsylvania (Draft Technical Guidance Document 310-2137-001, March 2014,

p. 7). Notably, PADEP to date has not identified any nontidal Riverine wetland habitat types:

Some Pennsylvania Wetland Habitat Types.

LAB	Lacustrine Aquatic Bed
LEM	Lacustrine Emergent
LFL	Lacustrine Flat
PAB	Palustrine Aquatic Bed
PEM	Palustrine Emergent
PFL	Palustrine Flat
PFO	Palustrine Forested
PSS	Palustrine Scrub/Shrub

Lacustrine Emergent Wetland and Lacustrine Aquatic Bed.

Palustrine wetlands are the most numerous and widespread kinds in Pennsylvania, accounting for 97% of the wetlands mapped in the Commonwealth by the National Wetland Inventory from high-elevation aerial photos taken during the late1970s and early 1980s (Tiner 1990). National Wetland Inventory mapping is a useful tool whose results are valuable for regional wildlife resource management, but it significantly omits many forested wetlands in Pennsylvania and is not a reliable guide to regulated wetland locations or boundaries.

Nevertheless, its incomplete and approximate data are readily available online and often are displayed on maps generated by geographical information systems. Hydric soil map units in county soil maps and wetland patterns on US Geological Survey topographic quadrangles also offer clues to wetland locations. But the actual extent of wetlands and streams can be determined only by field delineation of specific properties when construction activities are proposed.

The principal kinds of vegetation found in Palustrine wetlands are classed as forest (PFO), scrub (PSS), and herbland (PEM) based on visual observation and/or aerial photographs. Available statistics probably underestimate the proportion of forested wetlands in Pennsylvania, inasmuch as they are based on aerial photographs rather than field investigation and omit forested wetlands not distinguishable remotely. Palustrine flats (FL) devoid of vegetation are not common. The focus of vegetation classification is on the size and structure of the general mass of vegetation present in the landscape. An individual plant, depending on species, can pass through the structural stages of herb, shrub, and tree as it grows in wetlands or uplands. The US Fish and Wildlife Service has reported their estimate of cover types of National Wetland Inventory wetlands in Pennsylvania based on 1975-1985 aerial photographs (Tiner 1990):

Palustrine Forests.

Delhaas Woods, Bucks County. Photograph by Roger Earl Latham.

Columbus Bog, State Game Lands 197, Warren County. Photograph by Paul Wiegman.

Acres of National Wetland Inventory Wetlands in Pennsylvania, 1975-1985.

Palustrine Wetlands	
Emergent	*52,338 a*
Deciduous Forested	*146,715 a*
Evergreen Forested	*31,204 a*
Deciduous Scrub-Shrub	*47,539 a*
Evergreen Scrub-Shrub	*1,849 a*
Mixed Deciduous Shrub-Emergent	*25,000 a*
Open Water	*61,841 a*
Other Mixed Types	*26,242 a*
Total Palustrine Wetlands	*392,728 a*
Lacustrine Wetlands	*8,521 a*
Riverine Wetlands	*2,675 a*
PENNSYLVANIA WETLANDS	*403,924 a*

Forest vegetation (FO) is dominated by trees at least 3 inches in minimum trunk diameter measured 4.5 feet above the ground and at least 20 feet tall. Shrubs and herbs can grow beneath the canopy trees, or the forest floor can be essentially bare. Scrub (SS) is dominated by shrubs with multiple stems less than 3 inches in diameter and rarely taller than 20 feet. Herbs can be abundant beneath the shrubs but trees are few; light tends to reach the land surface to a much greater degree than in forests. Herblands (EM) are generally devoid of woody plants but instead support various kinds of non-woody, herbaceous higher plants that emerge from the soil surface. Their plant cover can be sparse or dense. Tracts of land that qualify as forest, scrub, or herbland may intergrade and are mapped as mixed types (for example, FO/SS). The forest, scrub, and herbland categories each can be subdivided into numerous subtypes, depending on the purpose of such classification and appropriate level of detail. For example, Palustrine forest and scrub polygons on maps can be broadleaf deciduous (assigned the modifier “1” by the National Wetland Inventory, as in “PFO1”) or needleaf evergreen (“PFO4”); emergent herbs can be persistent year-round (“1” as in “PEM1”) or nonpersistent (“PEM2”), and any of these modifiers

can be further supplemented by codes for dominant plant genus or species or for other ecosystem attributes where more precise distinctions are needed.

In Pennsylvania Palustrine ecosystems, forested wetlands are more extensive than scrub and herbaceous wetlands. Natural plant succession generally trends toward forest conditions in eastern North America (Braun 1950, Küchler 1964), and thus herbaceous and scrub wetlands tend to reflect earlier stages of natural post-disturbance succession than forested wetlands. The first-approximation airphoto mapping of Pennsylvania wetlands by the US Fish and Wildlife Service reported deciduous forests making up 37% of Palustrine wetlands; evergreen forest, 8%; deciduous scrub, 12%; evergreen scrub, <0.1%; mixed deciduous scrub-herbland, 6%; herbland, 13%; open water (including farm ponds), 16%; and other mixed types, 7% based on 1975-1985 aerial photographs (Tiner 1990). Under natural conditions the forest community is disrupted occasionally by storms, fire, and beaver activity. Human activities today are a much more common source of forest removal. Not all herblands, however, are rapidly changing categories of plant succession on their way to becoming forests; some can persist naturally for long periods of time as viewed by humans. The plants found in particular wetland communities can range from diverse species to almost monotypic where invasives have become established.

State and federal agencies that keep records of wetlands and wetland modifications use these vegetation types for data collection and analysis. Each distinctive vegetation type also is associated with characteristic functions. Herbaceous wetland vegetation is capable of being reestablished relatively quickly following temporary disturbance, within only a few growing seasons, if soil and hydrologic conditions are favorable. Shrubs require additional years to reach full size, and forest trees require decades for canopy closure, even where soil disturbance has not been severe. Diverse populations of desirable native species can require long periods of time to become established in disturbed or newly created wetlands.

Functions of Pennsylvania Wetlands

This section discusses the functions listed above (as set forth in 25 *Pa. Code* 105.1) that are typically associated with Palustrine forested (PFO) wetlands and compares them with similar functions in scrub (PSS) and herbaceous (PEM) wetlands. These functions are subject to disruption by human activities as well as by catastrophic occurrences of weather (hurricanes, tornadoes), ice storms, landslides, floods, and fires. Reductions in some functions may accompany increases in others.

The PADEP list of nine wetland functions in Chapter 105 regulations is reasonably comprehensive and suited to project-scale analysis based on the specific acreage of wetlands affected by an individual permittee. Current regulations do not focus on quantitative annual productivity of timber or wildlife, removal of air pollutants, carbon sequestration, or less tangible functions such as

aesthetic or historic/cultural appreciation. Nor do they require measurement of the values of any identified functions to individuals or groups. They do not specify how to compare the relative values of different functions, how to index current, past, or future functions of specific wetlands to generally accepted "reference" natural wetlands, call attention to the context of land surrounding a wetland, address the scarcity of a vegetation type, or provide for actual consideration of cumulative wetland impacts beyond an individual permit. PADEP long has found it virtually impossible to consider cumulative impacts, even for a single large project, because of its longstanding willingness to consider permits for fragments of a project on a piecemeal basis independently. PADEP does not expect an applicant to address its entire single project in a joint permit submission, much less analyze its proposed impacts cumulatively with those of other permittees over large areas. PADEP also does not focus on the uniqueness or heritage value of specific wetlands (aside from their potential for classing a wetland as having Exceptional Value) or a wetland's actual replaceability or irreplaceability, should damage be authorized.

1. Natural Biological Functions and General Habitat

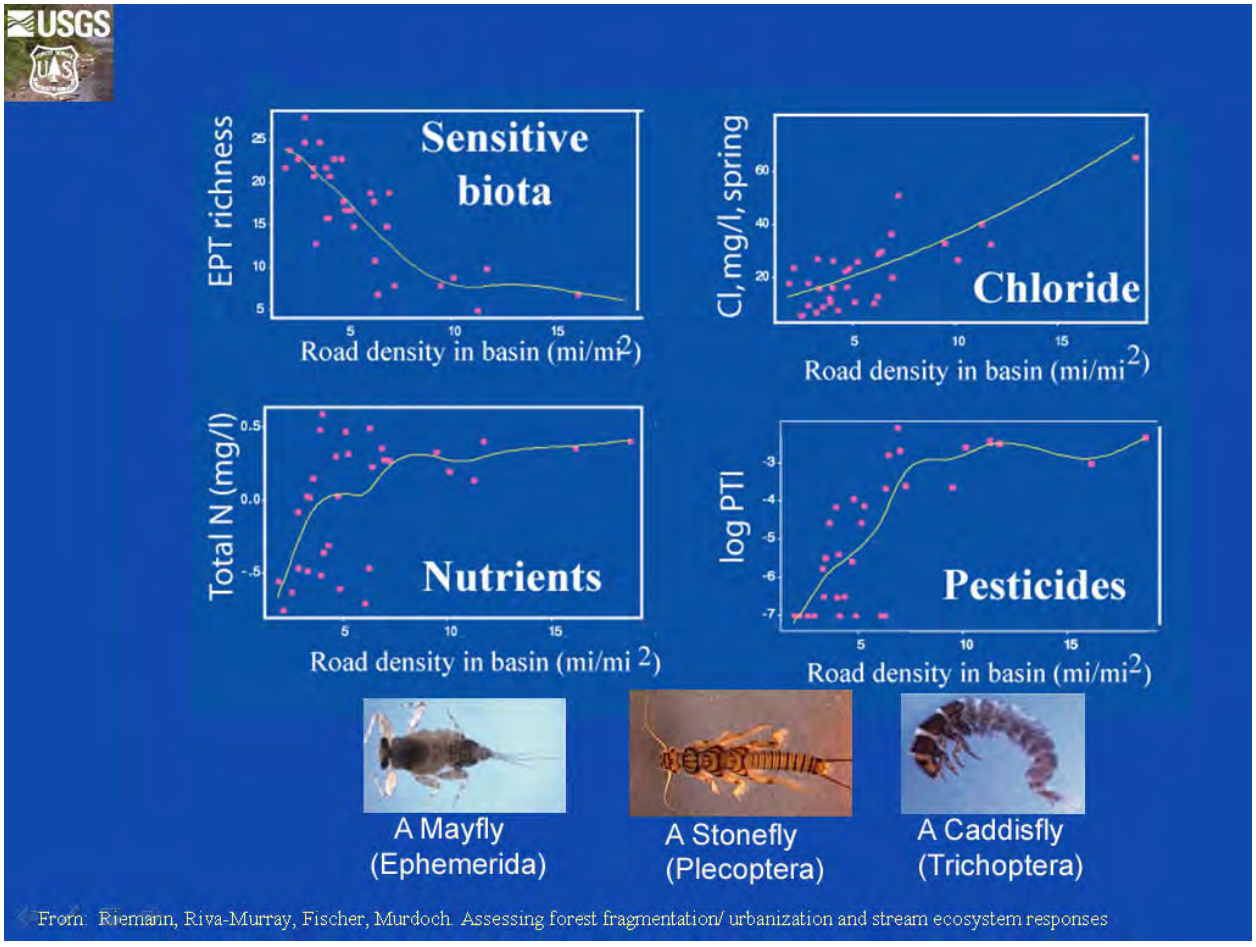
Natural biological functions of all wetlands include food chain production, general habitat, and resting-nesting-spawning-rearing sites for animals and fish. Many rare species of plants and animals are directly dependent on wetland habitats. Trees are the largest kinds of plants and have the greatest ability to modify the environmental effects of solar radiation, precipitation, temperature, humidity, and air quality as a result of their above-ground biomass. These natural, localized environmental modifications are of vital importance to the other plants and to the animals that live within and beneath forest cover. Tree leaves produce more tons of biomass per acre than shrubs for consumption by grazers and accumulate larger standing crops of organic material above ground. Tree trunks and limbs provide food for some animals and homes for many, with more complex structure than scrubs or herblands.

Pennsylvania forests consist of a wide variety of broadleaf deciduous trees, each species of which provides a somewhat different diet to the consumers that depend on it (Zimmerman *et al*. 2012; McShea & Healy 2002). Oaks, maples, ashes, elms, cherries, birches, and beech reflect the ancient geological history of Appalachia, and they returned to glaciated regions when the Pleistocene ice sheets melted. Pennsylvania forests also support many needleaf evergreen trees such as pines, hemlocks, and spruces. Very few stands of unharvested primeval forest remain in Pennsylvania; most of its forests have regrown following two or more episodes of intensive logging, burning, and other human disturbance during the past four centuries---episodes that have greatly affected the streams of the Commonwealth. Closed canopy forest consisting of mature trees requires about a century to recover to a recognizable mature forest structure after fire or clearcutting. About one third of Pennsylvania's forest stands are 80 years old or more; only 7%, 100 years old or more (McCaskill *et al*.

2013). Regenerated forest stands may or may not resemble their predecessors in their species composition when examined in detail, and the largest regrown individual trees are significantly smaller than historic records document as inherited by European colonists. Selective harvesting can remove key forest constituents, thereby reducing habitat value, and the forest canopy is further disrupted by logging roads, well pads, pipeline rights-of-way, borrow areas, and spills of fuel, brine, and other pollutants. Various kinds of shrubs and herbs grow only beneath a mature forest canopy. Wood ducks (*Aix sponsa*), a particularly handsome native species of waterfowl, require tree cavities for nesting as well as nearby water.

Trees growing in adjacent wetlands and streambanks are the major source of food for aquatic organisms in small, headwater streams. The intensity of ongoing human disturbance on the streams of forested areas can be estimated by the linear extent of roads per unit area. As summarized graphically by the United States Forest Service and US Geological Survey, human activity as approximated by road density has a dramatic effect on the quality of streams for sensitive aquatic insects that form the base of the aquatic food chain:

Road Density and Aquatic Parameters.



Both broadleaf and evergreen trees can dominate Pennsylvania wetlands, although broadleaf trees remain much more abundant (McCaskill *et al*. 2013). The value of forested wetlands to wildlife and to landowners is affected by the number of kinds of trees and other plants present (species diversity), their density and biomass (timber volume), the amount of dead timber standing and on the ground, the amount of grazing by domestic livestock and browsing by white-tailed deer, and the proportion of non-natives present. Diverse, high-quality vegetation is at greatest risk of human degradation and is the most difficult to restore (Olson and Doherty 2011). Wetland forests provide nesting, rearing, resting, and feeding sites for birds and mammals. One third of the bird species in the United States depend on wetlands (230 of 636; Welsch *et al*. 1995). Bears spend 60% of their time in forested wetlands during spring and summer (Newton 1988).

Unfragmented wetland forests are of great importance to many declining species of migratory songbirds. Wet forest floors are attractive wintering areas in which endangered bog turtles hibernate, and thick stands of evergreens shelter wintering deer and other animals. As already noted, the nutrients derived from tree leaves and twigs are vital to the macroinvertebrates and fish of Pennsylvania streams. Forest ecosystems are limited in their growth capability and affected in species composition by the availability of nutrients provided by the weathering of rock and transported in by air masses. The carbon from tree litter in turn can make up 99% of the total dissolved organic carbon at the base of the aquatic food web in forested streams (Stoler and Relyea 2011). Isolated vernal pools free of predatory fish are critically important to many uncommon reptiles and amphibians whose populations are dwindling. Discharges of stormwater, waste chemicals, and rubbish can degrade general habitat functions in forest and other wetlands.

Permanent forest disruption across Pennsylvania wetlands and uplands.

Scrub wetlands accumulate less standing biomass than mature forests. Hence any of the functions that derive from quantity of biomass are reduced in scrub as compared with forest wetlands, such as influence on microclimate, the amount of organic matter available for consumers of plant biomass, or the protection offered to soil from erosion. Some herbaceous wetlands can produce biomass in quantities rivaling forests above and below ground, but they lack the structural diversification of above-ground biomass of the woody wetlands. For animals adapted to herbaceous wetlands, such ecosystems provide important general habitat, nesting, resting, and rearing sites. The microtopography of hummocks provides habitat diversity critical to many species. Temporarily or permanently inundated herbaceous wetlands linked to streams and lakes have key importance as spawning and nursery grounds for fish, and inundated scrub wetlands are more common than inundated forests in Pennsylvania. The scrubs and sedge meadows with deep organic deposits associated with very wet herbaceous wetlands are prime spring and summer areas for various reptiles including the endangered bog turtle (*Glyptemys muehlenbergii*). Bog turtles prefer to overwinter in mats of tree roots where emerging groundwater warms near-surface temperatures. Herbaceous wetlands are of special importance to migrating waterfowl.

2. Environmental Study Areas and Refuges

Forested wetlands can serve as environmental study areas, particularly when located near schools, in public parks, and on other sites available to the public. Because natural plant succession in Pennsylvania normally trends toward forest vegetation, forests usually characterize refuges and sanctuaries relatively undisturbed by people, and forested wetlands typically provide high quality habitat to wildlife. The significance of forest cover to wetland wildlife increases as the size of wetlands decreases, particularly in landscapes with intensive human activity.

Scrub and herbaceous wetlands also can serve as study areas and biological refuges. They are less screened visually and aurally from adjacent human activities by their relatively lower quantities of biomass. They provide key habitat for wetland plants and animals that require open sun reaching the soil surface. Herbaceous wetlands are prime locations for birders.

3. Water Quality and Quantity Protection and Drainage Patterns

Forest wetland vegetation has maximal effect on processes affecting water movement and interaction with the land. By their mass, trees are able to slow the energy of falling raindrops and thereby limit soil erosion. Similarly, their mass and shade render the affected ground beneath the trees moister and cooler than nearby areas open to the sun. Decaying leaves provide a surface that readily accepts precipitation and allows it to infiltrate soil rather than quickly running off the surface.

The interflow through soils in turn contributes to natural extended flow of streams, minimizing both flooding and stream dryup. Nutrients can be bound up in tree trunks for centuries, and thereby kept out of waterways. The complex chemical reactions in wetland soils allow bacterial denitrification fostered by the carbon from leaves and vital to preventing excess nitrate-nitrogen from reaching streams. Wetland tree roots also can help anchor banks of streams against erosion. Forest loss to other land uses in Pennsylvania occurs at the rate of about 150 acres per day (McCaskill *et al*. 2013). Presumably most of these converted lands are not wetland forests, inasmuch as PADEP acknowledges the loss of less than 100 acres of all wetlands annually via individual permits, including forested wetlands.

Scrub and nonpersistent herbaceous wetlands stockpile less biomass on the land surface year-round than forested wetlands. They may offer less protection to the soil than forested wetlands, and their smaller roots may provide less resistance to physical erosion of streambanks.

Discharges of wastewater can contain pollutants at sufficient concentrations to overwhelm the ability of natural wetland systems to accommodate the pollutants, resulting in severe damage to the wetland ecosystems by manure, sewage, spilled brine, oil, and other chemicals. Rubbish also can degrade general habitat functions in forest and other wetlands.

4. Shoreline Protection and Stormwater Shielding

Aside from those on the banks of lakes and large rivers, forested wetlands in Pennsylvania generally have limited opportunity to shield other areas from wave and storm damage. Tree roots can stabilize streambanks large and small against stormwater erosion. To a lesser degree scrub wetlands can function similarly. Shrub willows often are planted to stabilize shorelines.

Some herbaceous wetlands occupy the shallow fringes of large water bodies, where they serve to reduce wave action and encourage sedimentation (thereby protecting water quality).

5. Flood Storage

Forested wetlands often serve as temporary storage areas for storm and flood waters. The economic value of such storage increases annually as flood damages rise in response to increased runoff from a growing human population, impervious surfaces from ever-expanding land development, and storm events of increasing severity driven by global warming in response to the burning of fossil fuels. Many forest ecosystems are adjusted to and dependent upon seasonal flooding, unlike most human structures that are easily damaged even by short-term inundation during flood peaks. Scrub and herbaceous wetlands, provided that they are suitably located, can function equally as well as forested wetlands for temporary

stormwater storage, although they may not shade the stored water so effectively and therefore not keep its temperature so low as a dense forest cover.

6. Groundwater Discharge

Spring seep areas are characteristic along the base of slopes in Pennsylvania forested wetlands. The forest shade keeps summer temperatures low as groundwater travels over the land surface toward headwater streams. Trout are a major feature of Pennsylvania streams and much sought-after by anglers. Many Pennsylvania streams have water near the limit of summer warmth that trout can tolerate. Forested wetlands along watercourses are essential to maintaining temperatures low enough for trout to survive and reproduce as global warming continues in response primarily to the burning of fossil fuels. Conversely, because of the warmth of groundwater, spring seeps may become snow-free earlier than dry uplands, and thereby attract feeding turkeys and other wildlife.

Shrub and herbaceous wetlands also can be associated with seeps flowing toward small streams. They are less able to keep surface water temperatures low than forests because of their lesser shade, but they may transpire fewer gallons of water during the course of a hot day. As mentioned previously, groundwater seeps closely associated with masses of tree roots are especially attractive areas for overwintering bog turtles.

Forested Wetland with Seeping Groundwater Discharge.

7. Groundwater Recharge

Countless local topographic depressions in forested wetlands store precipitation, slow its movement toward streams during periods of flood, and enable it to recharge local groundwater during wet seasons. Recharged groundwater, in turn, typically finds outlets to local streams. Recharge can be greater in scrub and herbaceous wetland depressions, because their plant cover transpires less water into the atmosphere than large trees.

8. Pollution Prevention and Sediment Control

Forested wetlands prevent pollution of water bodies by reducing the erosive force of rainstorms. Their trees break the fall of droplets hitting leaves and branches; they anchor the soil with roots and cover it with absorptive leaf litter; their roots bind streambank soils against erosion. Forested wetland soils enable sedimentation, denitrification, and other biogeochemical processing as surface waters pass through. Scrub and herbaceous wetlands can function comparably, but provide less physical protection against soil erosion by precipitation. Forested buffers surrounding wetlands can provide the most effective long-term protection of wetlands from sediment influx originating in disturbed lands.

9. Human Recreation

Wetland forests provide recreational opportunities for Pennsylvania citizens and visitors, calling forth significant contributions to the economy of the Commonwealth on a sustainable basis by those who use the outdoors. Great numbers of people find the seasonally changing display of blooms and colored leaves highly attractive and a sharp contrast to landscapes in urban centers. Recreational hunters seek the game animals---deer, bear, squirrels, waterfowl, and other game birds---that depend on wetland as well as upland forests. Anglers depend on riparian forests to keep the Pennsylvania streams cool enough and to supply food for salmonids. Forested wetlands are especially effective in providing humans with natural landscapes contrasting sharply with urban commercial and industrial environments.

Scrub and herbaceous wetlands also provide recreational opportunities for hiking and for game habitat. Herbaceous wetlands often attract spectacular flocks of migratory waterfowl.

Palustrine Deciduous Scrub Opening in Needleaf-Dominated Bog on Peat.

Rosencrans Bog Natural Area, Clinton County. Photograph by Staff of The Western Pennsylvania Conservancy.

Through its recent draft technical guidance documents PADEP appears to be seeking to expand from a strictly acreage-based evaluation of wetland impacts and working instead toward a weighting of functions, indexing to reference ecosystems, and consideration of conditions adjacent to the affected wetland. State methodology also is just beginning to consider cumulative effects on a watershed basis, which is essential for rationally offsetting the negative side effects (externalities) of construction in wetlands. The proposed technical guidance draws conceptually on federally sponsored work on wetland functions that has been underway for twenty years (Smith *et al*., 1995) as well as the more recent work by Robert Brooks and his coworkers at Riparia, the Cooperative Wetlands Research Center at Pennsylvania State University. PADEP's current list of functions is displayed below.

Table 2
Wetland Functions and Their Value

Functions Related to Hydrologic Processes	Benefits, Products, and Services Resulting from the Wetland Function
Short-Term Storage of Surface Water: the temporary storage of surface water for short periods.	Onsite: Replenish soil moisture, import/export materials, conduit for organisms. Offsite: Reduce downstream peak discharge and volume and help maintain and improve water quality.
Long-Term Storage of Surface Water: the temporary storage of surface water for long periods.	Onsite: Provide habitat and maintain physical and biogeochemical processes. Offsite: Reduce dissolved and particulate loading and help maintain and improve surface water quality.
Storage of Subsurface Water: the storage of subsurface water.	Onsite: Maintain biogeochemical processes. Offsite: Recharge surficial aquifers and maintain baseflow and seasonal flow in streams.
Moderation of Groundwater Flow or Discharge: the moderation of groundwater flow or groundwater discharge.	Onsite: Maintain habitat. Offsite: Maintain groundwater storage, baseflow, seasonal flows, and surface water temperatures.
Dissipation of Energy: the reduction of energy in moving water at the land/water interface.	Onsite: Contribute to nutrient capital of ecosystem Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality
Functions Related to Biogeochemical Processes	**Benefits, Products, and Services Resulting from the Wetland Function**
Cycling of Nutrients: the conversion of elements from one form to another through abiotic and biotic processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Removal of Elements and Compounds: the removal of nutrients, contaminants, or other elements and compounds on a short-term or long-term basis through burial, incorporation into biomass, or biochemical reactions.	Onsite: Contributes to nutrients capital of ecosystem. Contaminants are removed, or rendered innocuous. Offsite: Reduced downstream loading helps to maintain or improve surface water quality.
Retention of Particulates: the retention of organic and inorganic particulates on a short-term or long-term basis through physical processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Export of Organic Carbon: the export of dissolved or particulate organic carbon.	Onsite: Enhances decomposition and mobilization of metals. Offsite: Supports aquatic food webs and downstream biogeochemical processes.
Functions Related to Habitat	**Benefits, Goods and Services Resulting from the Wetland Function**
Maintenance of Plant and Animal Communities: the maintenance of plant and animal community that is characteristic with respect to species composition, abundance, and age structure.	Onsite: Maintain habitat for plants and animals (e.g., endangered species and critical habitats), for rest and agriculture products, and aesthetic, recreational, and educational opportunities. Offsite: Maintain corridors between habitat islands and landscape/regional biodiversity.

Stressors

The functional values of wetlands can be reduced by many stressors, most of which are directly or indirectly the result of human activity and also are more intense and persistent than natural disruptive forces. The evolving PADEP list of stressors lists 37 kinds that are readily observable in the field, grouped into five categories (Draft Technical Guidance Document 310-2137-002, March 2014, p. 33). They prudently have left a blank for other, unlisted stressors in each of the five categories, for less commonly encountered conditions.

PADEP-listed Wetland Stressors.

Vegetation Alteration
Mowing
Moderate livestock grazing (within one year)
Crops (annual row crops, within one year)
Selective tree harvesting/cutting (>50% removal, within 5 years)
Right-of-way clearing (mechanical or chemical)
Clear cutting or Brush cutting (mechanized removal of shrubs and saplings)
Removal of woody debris
Aquatic weed control (mechanical or herbicide)
Excessive herbivory (deer, muskrat, nutria, carp, insects, etc.)
Plantation (conversion from typical natural tree species, including orchards)
Other:
Total Number:
Hydrologic Modification
Ditching, tile draining, or other dewatering methods
Dike/weir/dam
Filling/grading
Dredging/excavation
Stormwater inputs (culvert or similar concentrated urban runoff)
Microtopographic alterations (e.g., plowing, forestry bedding, skidder/ATV tracks)
Dead or dying trees (trunks still standing)
Thermal alteration (power plant or industrial discharges with evidence of high temperatures)
Stream alteration (channelization or incision)
Other:
Total Number:
Sedimentation
Sediment deposits/plumes
Eroding banks/slopes
Active construction (earth disturbance for development)
Active plowing (plowing for crop planting in past year)
Intensive livestock grazing (in one year, ground is >50% bare)
Active selective forestry harvesting (within one year)
Active forest harvesting (within two years, includes roads, borrow areas, pads, etc.)
Turbidity (moderate concentration of suspended solids in the water column, obvious sediment discharges)
Other:
Total Number:

Eutrophication
Direct discharges from agricultural feedlots, manure pits, etc.
Direct discharges from septic or sewage treatment plants, fish hatcheries, etc.
Heavy or moderately heavy formation of algal mats
Other:
Total Number:
Contaminant/Toxicity
Severe vegetation stress (source unknown or suspected)
Obvious spills, discharges, plumes, odors, etc.
Acidic drainages (mined sites, quarries, road cuts)
Point discharges from adjacent industrial facilities, landfills, railroad yards, or comparable sites
Chemical defoliation (majority of herbaceous and woody plants affected, within one year)
Fish or wildlife kills or obvious disease or abnormalities observed
Excessive garbage/dumping
Other:
Total Number:

The more numerous the stressors affecting a wetland, the lower its value. When rating the value of wetland conditions, the proposed PADEP scoring also assigns higher value to wetlands surrounded by forests than to those surrounded by scrub, and assigns higher value to those wetlands surrounded by scrub than to those surrounded by herblands or ponds. Managed wetland buffers are scored lower than wild, unmanaged buffers (Draft Technical Guidance Document 310-2137-002, March 2014, p. 33).

In 2006 PADEP sampled 204 wetlands and used their evolving protocols to rank the condition of those wetlands (PADEP 2014c). How representative the sampled wetlands might be of Pennsylvania wetlands as a whole was not stated, but the rankings from their protocol testing were reported as follows:

Condition Category	Number of Wetlands	Total Acreage	Percent of Resource
Highest	13	127.74	6.10%
High	59	556.19	26.70%
Medium	41	468.89	22.50%
Low	91	930.07	44.70%
Totals	**204**	**2082.88**	**100.00%**

Conversion of Woody Wetlands to Herbaceous Wetlands

Forest and scrub wetlands can be converted to herbaceous wetlands in various ways with effects more or less catastrophic, even if wetland conditions are not intentionally obliterated permanently to enable the construction of roads, buildings, or farm fields. Woody stems can be cut at the ground surface and merely the aboveground trees and shrubs removed, if the goal is to reduce disruption of the soil. More invasively, tree stumps and shrub roots can be grubbed. Biologically active soils can be removed entirely. Hydrology can be diverted or impounded. The amounts and kinds of functions lost and gained will be determined by what conditions previously existed in the wetland as well as the nature and extent of disturbance. If any one of the three major wetland characteristics (hydrophytic vegetation, hydric soils, or hydrology) is not or cannot be restored to natural conditions, then the conversion of wetland to non-wetland will be permanent. The conversion of forested wetlands to scrub or herbaceous wetlands is not readily reversible, inasmuch as forest regrowth at best requires many decades, and may be intentionally prevented by repeated cutting or by spraying herbicides.

When wetland vegetation is changed by people from forest or scrub to herbaceous, many of the wetland's functions can be altered. Detailed study is necessary in order to predict accurately the probable changes and compose plans for appropriate mitigation, because the affected functions will vary at each location supporting a natural wetland.

Where naturally variable wetland hydrology has been restored, some generalist wetland plants usually will follow quickly unless toxic substances also have been introduced, and hydric soils eventually will become recognizable after many years of weathering have elapsed. Pennsylvania wetlands evolved after the retreat of glacial ice, and their biota retains the ability to recover following natural disturbances that are less drastic than those of current technology. Unless artificial plantings are made to accelerate the establishment of desirable species, however, invasives that thrive in human-disturbed wetlands are likely to invade and crowd out preferred species of native plants. Construction activities usually provide ample opportunities for invasive plants and animals to arrive at construction sites. Various online sources provide links to information on invasive species, including those of the Governor's Invasive Species Council of Pennsylvania (www.invasivespeciescouncil.com), the Pennsylvania Department of Conservation and Natural Resources (www.dcnr.state.pa.us/conservationscience/), and the US Forest Service (www.fs.fed.us/invasivespecies).

If the objective is to restore pre-disturbance native wetland vegetation, then near-replacement of pre-disturbance hydrology and soils is most likely to yield the desired plant community. Such replacement only succeeds where careful investigation of plants, soils, and hydrology preceded the wetland disturbance, so that mitigation site modification effectively can mimic the structure of the lost

wetland. Light-tolerant herbaceous and scrub wetland plants can be restored more rapidly than forest vegetation, which takes many years for trees to reach mature size and natural diversity even where maximally successful. Protection of new plantings of native woody species from browsing deer and rabbits often is critical for the survival of the plants during the early years after wetland creation or restoration, and supplemental watering may be necessary during unusually dry years while root systems are being formed. Plantings of herbaceous wetlands can be devastated by migrating waterfowl. Moreover, the early-succession trees which will thrive in an open wetland only slowly are replaced by shade-tolerant species of late forest succession. Late-succession native herbs characteristic of mature Pennsylvania forested wetlands would not be expected to grow until the forest canopy has become reestablished and soil formation has proceeded to approximate natural conditions.

Compensatory mitigation in the form of replacement wetland creation or degraded wetland restoration is intended to result in functioning wetlands that do not require ongoing human intervention. Pennsylvania permit conditions long have required five years of monitoring for wetland restoration and creation projects along with written reports to PADEP, but post-construction monitoring has been sporadic at best and approved wetland restoration plans often have been unsuccessful in execution. Ponds are much easier and quicker to build than forested wetlands, but do not provide mitigation for various wetland functions. Similarly, basins engineered to detain stormwater flows from developed areas seldom result in high-value wetlands.

As one illustrative example of the conversion of woody wetlands to herbaceous cover, pipelines can be considered. The excavation of trenches for miles uphill, downhill, and across streams and wetlands is a catastrophic event followed by some measure of soil cover replacement on top of the pipes. But few pipeline operators

Pipeline construction through Pennsylvania wetlands. The corridor will be maintained free of woody vegetation after the pipe is buried.

Herbaceous Wetland 40 Years after Pipeline Installation.

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are prepared to allow reforestation to obscure right-of-way conditions. Thus pipelines are likely to involve vegetation stressors such as right-of-way clearing, clear-cutting of brush, and removal of woody debris both prior to and for the long term subsequent to pipeline installation. Mechanical clearing using equipment occurs, as does spraying with non-selective chemical herbicides to prevent the reestablishment of trees and shrubs so that rights-of-way can be quickly inspected on the ground and from the air.

In summary, the most probable, usually adverse effects of human conversion of forest or scrub to herbaceous wetlands on PADEP-listed wetland functions, the following would be expected and should be considered carefully:

1. **General Habitat and Natural Biological Functions**
   Aboveground biomass: decrease
   Forest interior habitat: loss
   Structural diversity: decrease within converted wetland
   Visual and aural screening from human activity: loss
   Local climate amelioration: decrease
   Evergreen winter cover for wildlife: loss
   Suitability for shade-loving species of plants: loss
   Production of mast (such as acorns) for wildlife: loss

Exposure to harsh wind, ice, sun: increase
Localized effects of global warming on biota: increase

2. **Study Areas and Refuges**
   Structural diversity of ecosystem: decrease within converted wetland
   Species diversity of plants and animals: decrease within converted wetland
   Visual and aural screening from human activity: loss
   Rare, ancient trees: loss

3. **Drainage Patterns, Water Quantity, and Water Quality**
   Streambank anchoring against erosion: decrease
   Soil stabilization: decrease
   Erosion and sedimentation: increase
   Nutrient storage in ecosystem: decrease
   Maintenance of cold water temperature for trout: decrease

4. **Storm Damage Shielding and Shoreline Protection**
   Streambank stabilization: decrease

5. **Flood Storage**
   Storage volume: no significant change

6. **Groundwater Discharge**
   Volume discharged: increase (reduced transpiration)

7. **Groundwater Recharge**
   Volume recharged: increase (if soil not disrupted)

8. **Pollution Prevention and Sediment Control**
   Erosion and sedimentation control: decrease

9. **Human Recreation**
   Landscape aesthetics: disruption
   Species composition, plants and animals: change
   Forest interior species: loss
   Maintenance of cold water temperature for trout: decrease
   View and hiking corridors: increase

How much functional loss will occur as a result of authorized conversion from forest or scrub to herbland at any wetland location will depend on the functions initially present in the forested wetland, the severity of the disruption to the elements of the environment such as its soil and surface elevation, the location of the converted area in the landscape, and its connection with other wetlands, especially along stream corridors. As some functions decrease, others may increase. The degree to which impacts are negative also depends on the context of reference: "edge" species such as whitetailed deer benefit from forest

fragmentation. Given the complexity of the natural world, under some sets of circumstances an anticipated negative change actually could prove beneficial. The functional loss of forested wetland is never quickly reversible, even if active maintenance were to stop, nor is it capable of offsite mitigation except, at best, until after long time delays.

Not currently identified by PADEP in its list of functions, conversion of forest to herbaceous wetland also entails a reduction in the ability of the wetland to affect human climate and to reduce air pollution. Herbaceous wetlands cannot rival forests in providing shade and screening people from wind. Likewise, they cannot promote the deposition of airborne pollutant particles or take up as much gaseous pollution as forest trees.

In principle, some of the functional losses of vegetation conversion eventually can be replaced by successful wetland mitigation onsite or offsite. But the actual substitution of lost functions by compensatory wetlands is not routine.

Wetland Compensatory Restoration and Creation

Because wetland damage and destruction routinely are authorized by permits, agencies by regulation are to require the restoration of temporary damage and the offsetting replacement of permanent loss of natural wetlands. A plan for the mitigation of unavoidable impacts by regulation is required as part of every individual joint permit application for wetland encroachments in Pennsylvania, other than "small" projects deemed by PADEP to have no significant impact on safety or protection of life, health, or the environment [25 *Pa. Code* 105.13(d)(1)(ix)]. Mitigation is defined (at 25 *Pa. Code* 105.1) as

> An action undertaken to accomplish one or more of the following:
>
> Avoid and minimize impacts by limiting the degree or magnitude of the action and its implementation.
>
> Rectify the impact by repairing, rehabilitating or restoring the impacted environment.
>
> Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.
>
> If the impact cannot be eliminated by [the foregoing measures], compensate for the impact by replacing the environment impacted by the project or by providing substitute resources or environments.

PADEP records fewer than 100 acres of wetlands authorized for damage annually under individual permits during recent years, along with about 40 miles of streams (PADEP 2014c). These wetland statistics do not include losses through construction authorized by general permits. The statistics also do not include enforcement against unauthorized encroachments into streams and wetlands. (These stream statistics omit altogether about half of the land area of

the Commonwealth that occupies small watersheds where stream, but not wetland, destruction is authorized automatically by waiver.)

Since the 1990s PADEP has sought 1:1 minimum replacement for wetland acreage and functions, with a preference for mitigation adjacent to the loss and on the same property. Mitigation has been designed on an acreage replacement basis, typically with no allowance for less than complete success or the time during which wetland functions are absent. Functional replacement itself has seldom if ever been mandated. For enforcement cases, PADEP policy long has sought to require 2:1 acreage mitigation (PADEP 1992, 1997a). PADEP's stated preference has been for onsite mitigation close to the allowed wetland destruction rather than for remote offsite mitigation. Such mitigation would be undertaken by the permittee, who seldom is expert in wetland mitigation.

Because less intervention is required, the restoration of wetlands previously converted to agricultural uses typically is easier and less uncertain than conversion of uplands to wetlands. Wetland hydrology, for example, sometimes can be restored simply by crushing the drainage tiles installed by farmers in order to dry fields sufficiently for commercial crops. To the extent hydrology is removed temporarily, but then restored, wetland vegetation and some semblance of a wetland ecosystem can be recovered onsite where care is taken to reconstruct natural conditions insofar as practicable. Habitat functions often can be attained more readily in rural mitigation areas than adjacent to urban development sites where the restored or created wetlands are isolated from other areas of comparable habitat. Areas amenable to wetland restoration, however, often are located offsite at considerable distance from impacted areas and affected watersheds. Wetlands in stream valleys and floodplains do not necessarily substitute functionally for wetlands along headwater streams.

Successful wetland creation from dry land, even more than restoration, depends on careful identification of water budgets pre-construction to guide attempted restoration. Abundant field experience has demonstrated that small inaccuracies in analyzing or reconstructing hydrology will result either in dry non-wetlands or in open water ponds rather than vegetated wetlands.

Hydrology normally is removed by blocking the movement of water into a wetland (1) by diking or channelizing and diverting its flow and/or (2) by expediting the removal of water from a wetland by drainage pipes or pumps. Restoration of hydrology may require detailed attention to creating almost flat slopes, and often requires design for seasonal variability in wetness. Most natural wetlands, unlike typical farm ponds and detention basins, have very gently sloping land surfaces rather than abrupt banks. Effective wetness of surface soils within a wetland can be reduced by removal of natural vegetation on and adjacent to the mitigation area, impeding the recovery of wild plants and affecting the survival of replacement plantings. Hydrology derived from channelized stormwater can be toxic to wetland plants, if the stormwater brings in road salts, oil, excessive

nutrients, and other pollutants. Trees typically are less tolerant of salinity change than herbaceous plants (Adamus & Brandt 1990). Where urban runoff is the source of wetland hydrology, functional mitigation may be difficult to achieve.

Timely restoration of near-surface hydric soils that have wetland characteristics depends on the successful removal and segregation of topsoil, and then its replacement above the subsoil. By keeping holding time for stockpiled topsoil to a minimum, some of the natural seed bank can be salvaged to aid in wetland revegetation. Where the structure of the soil layers has been drastically altered, years are required for horizontal layering to become restored by natural weathering. If wetland hydrology was caused by impermeable subsurface layers such as clay lenses, and those are disrupted by excavation, capturing sufficient hydrology for wetland restoration may be impossible. If surface soil density is compacted, additional years are required for natural porosity to return along with the ability for water to penetrate (Stoler and Relyea 2011). The placement of only a few inches of soil on wetland trees and shrubs, as well as herbs, can be fatal to the disturbed plants. Mulch and short-lived cover crops can help stabilize soils without offering severe competition to desirable native wetland plants. A natural balance of groundwater recharge and discharge in constructed or restored wetlands is not easily achieved.

Given these technical considerations and the historical fact that practical humans long focused on draining and converting rather than restoring wetlands and wetland functions, the actual mitigation of wetland impacts has proved generally unsuccessful in Pennsylvania for many decades (*see*, for example, McCoy 1987, 1992; Kline 1991) and has not improved recently (Campbell *et al*. 2002, Cole & Shaffer 2002, Gebo & Brooks 2012, Hoeltje & Cole 2007, Kislinger 2008, PADEP 2014c). Seldom has mitigation created the same kind of wetlands as those damaged. Most attempted mitigation that succeeded in creating wet areas resulted in open water ponds rather than forested or scrub wetlands (Cole and Shaffer 2002). Monitoring and reporting on mitigation success on paper is required of applicants, but often not performed. PADEP staff seldom monitor wetland mitigation sites or require remedial measures of permittees.

PADEP has found that the ability of permittee-constructed mitigation

> to address the needs of a watershed is limited at best. Applicants generally do not have adequate resources to identify watershed needs, plan for and identify high value project sites, and/or secure rights to and produce significant restoration activities. (PADEP 2014c)

69 Permit Wetland Mitigations Scored by PADEP Interns, 1992-1995

Size (acres)	Success	Failure	Not Rated	% Success
0-.10	5	3	1	62.5
.10-.25	8	6	1	57.1
.25-.50	9	7	0	56.3
.50-1.0	11	3	0	78.6
1.0->	13	2	0	86.7
Total	46	21	2	68.7

Most Pennsylvania wetland impacts authorized by individual permit, after avoidance and minimization have been addressed, affect small acreages. Thus PADEP has implemented an acreage-based fee-in-lieu program to enable most permittees affecting small (0.5 acre or less) areas of wetland to substitute a one-time cash payment instead of undertaking their own construction of mitigation wetlands (PADEP 1997b). The half-acre "allowance" for cash contributions was deemed sufficient to allow any landowner enough wetland impact to build a house. Fees were set by PADEP based on its expectation that willing landowners across the Commonwealth would allow conversion of uplands to wetlands or restoration of wetlands with higher quality through voluntary cooperation with PADEP and the National Fish and Wildlife Foundation. This program has greatly assisted permittees, but it has not demonstrably resulted in compensatory wetland mitigation similar in kind or location to wetlands destroyed.

Contributions to the Washington, D.C.-based National Fish and Wildlife Foundation's Pennsylvania Wetland Replacement Project ID 95-096 became routine across the Commonwealth beginning in the 1990s. According to its web page, as of May 2014 this Foundation had sponsored 486 environmental enhancement projects of various kinds in Pennsylvania. Locational and descriptive information for these projects are displayed on an interactive map. But no data apparently exist comparing wetland acreage or functions lost to mitigation accomplished under the Pennsylvania in-lieu-fee program or identifying the geographical proximity of wetland losses versus gains on a watershed basis. Only first-time readers of PADEP regulations might expect any applicant eligible to use the Fund even to consider undertaking onsite mitigation, which is always far more expensive than scheduled contributions to the State's

Fund. The in-lieu fees long have represented a major subsidy to permittees from Pennsylvania residents and their environment (Schmid 1996a, b). Pennsylvania mitigation fees have been the same for Exceptional Value as for Other wetlands, and the acreage-based fees have been presumed to compensate for any and all wetland functions associated with the wetlands lost.

Pennsylvania Wetland Mitigation Replacement Fees (1997-2013).

De minimis impact less than or equal to .05 acre	$ 0.00
Greater than .05 acre to .10 acre	$ 500.00
Greater than .10 acre to .20 acre	$ 1,000.00
Greater than .20 acre to .30 acre	$ 2,500.00
Greater than .30 acre to .40 acre	$ 5,000.00
Greater than .40 acre to .50 acre	$ 7,500.00

Contributions to the Fund relieve permittees of any followup responsibility for mitigation monitoring or success. Between 1997 and 2013 the buying power of cash contributions to the Fund dwindled by about 30% due to inflation, while the market costs of wetland creation can be $100,000 per acre in some locations, according to the Pennsylvania Department of Transportation. Costs are less where free land and prison labor can be obtained (FHWA 2011). Moreover, the success of the wetland mitigation work done under PADEP's Replacement Project apparently has been limited and certainly has been sparsely reported. Pennsylvania's in-lieu-fee program was deemed unacceptable for use to satisfy federal wetland mitigation requirements in 2008, and its "grandfathering" expired in 2013 (33 CFR 332.8). Hence the PADEP currently is seeking federal approval for a new in-lieu-fee program (PADEP 2014c).

The generally laudable goals of the new program include (1) high quality mitigation addressing wetland functions as well as acreage, (2) ecologically based mitigation site selection, (3) efficiencies of scale in constructing, monitoring, and administering a few large mitigation projects instead of many small ones, (4) streamlined federal and State permit approvals, and (5) more effective accounting and compliance reporting (PADEP 2014c). PADEP claims that it has the expertise and staff to run an in-lieu-fee program effectively. As has been repeatedly demonstrated by PADEP staff and by independent academics, mitigation to date by permittees affecting more than the half acre of wetlands to which Fund contributions are limited typically has been of poor quality in Pennsylvania and has failed altogether in replacing the functions of wetlands lost.

The new PADEP technical guidance potentially represents an opportunity to have those who hope to benefit from damaging wetlands more effectively internalize the negative externalities of their conduct, a goal consistent with both Pennsylvania and federal law. It is not self-evident that the functions of multiple small, scattered wetlands high in the landscape can be replaced effectively by

larger wetlands in floodplains, and PADEP may be asked to address this issue, as well as many other technical details, prior to gaining federal approval for its proposed in-lieu-fee program. Unquestionably, more information will need to be generated during preparation and review of each application to damage wetlands, if new PADEP technical guidance is adopted along the lines of its current draft. A significant outcome should be the more effective tailoring of compensatory mitigation to the amount and type of wetland impacts. The full costs of mitigation should include both the risk of mitigation failure and the temporal lag between impacts and restoration of functions---which, for forested wetlands can be immense.

Only if this opportunity is fully exploited will future mitigation begin to compensate for permitted impacts in Pennsylvania. The new guidance also can provide a corrective to the mitigation failures and lack of accountability long prevalent in Pennsylvania, while reducing the previous economic subsidies encouraging private destruction of wetland resources. The new information available also should allow better public understanding of the external costs of development and the benefits of successful mitigation, particularly if public access to permit records is made electronically available.

It is high time that human behaviors with harmful side effects in Pennsylvania be mitigated more effectively to enable continued prosperity for its residents and the planet's survival, as well as compliance with Article 1, Section 27, of the Pennsylvania Constitution:

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

When completed, the new PADEP technical guidance may make possible the actual functional mitigation for conversion of forest and scrub wetlands to herbaceous wetlands. If effective, it also should help reduce so-called "natural" hazards from waters---hazards which are in fact failures of human design, construction, planning, and community development in areas subject to natural processes of stormwater movement. If the opportunity is missed, the alternative includes increased environmental plundering of remaining wetland resources, high costs for disaster survivors, especially the most vulnerable, as well as harm to communities and ever growing costs to taxpayers.

Completion of public review, PADEP revision, and implementation of the new technical guidance for wetland assessment and mitigation may take considerable time. Pennsylvania wetlands only slowly have begun to receive some attention from regulators in the context of damage by longwall (that is, high-extraction underground) bituminous coal mining, which was first allowed by Act 54 of 1994. PADEP long refused to recognize even the possibility of damage to wetlands from

longwall mining, but gradually has been implementing more thorough data collection for mine applications (Schmid & Co., Inc. 2000, 2010a, 2011a, 2012, 2013).

The minimal current PADEP information and review requirements for oil and gas permits provide virtually no assurance that wetlands will be identified and protected from this extractive industry, which currently is experiencing a boom across much of the Commonwealth. Similarly, PADEP has failed to protect too many streams, particularly those streams of highest ecological value (Van Rossum *et al*. 2011; Kunz 2011; Schmid & Co., Inc. 2010b). Oil and gas permit applications generate far less environmental information than coal mining applications. Proposed regulations governing surface oil and gas activities currently are under review (25 *Pa. Code* 78, Subchapter C). PADEP and the Environmental Quality Board are preparing responses to the 24,000 comments received on their proposed oil and gas regulations. New Chapter 78 regulations could specify protection for streams and wetlands far more effectively than the regulations they are replacing.

Whether the proposed wetland analysis and mitigation technical guidance will receive similar public attention remains to be seen. Its comment period is still open and likely to be extended.

Authorship

This report was prepared by James A. Schmid, a biogeographer and plant ecologist. Dr. Schmid received his BA from Columbia College and his MA and PhD from the University of Chicago. After serving as Instructor and Assistant Professor in the Department of Biological Sciences at Columbia University and Barnard College, he joined the environmental consulting firm of Jack McCormick & Associates of Devon, Pennsylvania. Since 1980 he has headed Schmid & Company of Media, Pennsylvania.

Dr. Schmid has analyzed and secured permits for some of the largest wetland mitigation projects in the mid Atlantic States, as well as a myriad of smaller projects. He is certified as a Senior Ecologist by the Ecological Society of America, as a Professional Wetland Scientist by the Society of Wetland Scientists, and as a Wetland Delineator by the Baltimore District, Army Corps of Engineers. He has served on the professional certification committees of the Ecological Society and the Society of Wetland Scientists.

When the US Fish & Wildlife Service Pleasantville Office evaluated actual compliance with approval conditions requiring mitigation by about 100 of the Clean Water Act Section 404 fill permits issued by the Corps of Engineers in the State of New Jersey during the period 1985-1992, every Schmid & Company mitigation project was judged in the field to exhibit full compliance with all permit requirements and mitigation goals. Schmid & Company mitigation projects

represented 21% of all the mitigation projects judged fully successful in New Jersey by USFWS in its written report to USEPA. Dr. Schmid analyzed and secured Wetland Mitigation Council approval for the first major freshwater mitigation bank in New Jersey on behalf of DuPont. That bank was donated to The Nature Conservancy.

Dr. Schmid has often analyzed environmental regulatory programs and commented on proposed regulations. His clients continue to include the construction industry, conservation groups, and government agencies, including the Pennsylvania Department of Environmental Protection.

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Impacts of Shale Gas Development on Bat Populations in the Northeastern United States

Indiana bat (*Myotis sodalis*). Photo credit: Bat Conservation International.

A report submitted to

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BACKGROUND

Natural gas development from shale is rapidly expanding across the US (Ground Water Protection Council GWPC and ALL Consulting 2009). Shale gas reservoirs, or plays, are distributed across the country (Fig 1.) and can be found at depths ranging from 152–4,115 meters (m). The most productive plays include the Barnett, Haynesville, Fayetteville, Woodford and Marcellus Shales (Zoback et al. 2010). In the northeastern US, the Devonian, Marcellus, and Utica shales extend across several states and are located within the Appalachian Basin Province (Coleman et al. 2011).

Figure 1. Location and size of shale gas reservoirs, or plays, in the United States. Source: US Energy Information Administration (USEIA) based on published data.

The process of producing natural gas from shale and other unconventional reservoirs (i.e., formations with low permeability and porosity) requires fracturing the rock formation. In high-volume hydraulic fracturing (HVHF) operations, highly pressurized fluid, consisting of water and various chemicals, is used to create these fractures. Suspended in the fluid is a propping agent, typically sand, which maintains the openings and allows gas to migrate to the well (Carter et al. 1996, Entrekin et al. 2011). To increase the volume of rock accessed by a single vertical well, operators rotate the drill and bore horizontally through the shale bed. Up to fifteen separate HVHF operations are possible per well (Kargbo et al. 2010).

OBJECTIVES

Concerns regarding the potential impacts to humans and the environment have grown in conjunction with the rapid expansion of shale gas development. Issues regarding water withdrawal, water contamination, habitat loss and degradation, impacts to terrestrial and aquatic ecosystems, and greenhouse gas (GHG) emissions surround HVHF operations. Moreover, no data exist on the possible adverse influence these operations have on bat populations. Because of recent concerns regarding rapidly declining bat populations in the northeastern US, there is

increasing concern about the additive effects HVHF operations could have on already imperiled bat species. This report will focus on the environmental effects associated with shale gas development and the potential impacts to bat populations in the region.

ENVIRONMENTAL IMPACTS

Water withdrawal. The HVHF process requires large volumes of water per well to fracture shale formations. Estimates ranging from 2 to 7 million gallons of water are used per operation, depending on conditions of the site (NYDEC 2011, Susquehanna River Basin Commission [SRBC] 2010, US Environmental Protection Agency [USEPA] 2011). In 2006, the estimated 35,000 fractured wells across the US used between 70–140 billion gallons of water, equivalent to the total amount withdrawn from drinking resources each year by 40–80 cities with populations of 50,000 people, or 1–2 cities of 2.5 million people (Halliburton 2008, USEPA 2011). Source water comes from either surface (e.g., streams or lakes) or ground water (e.g., aquifers). Water can be withdrawn from a nearby source or transported by trucks or a pipeline, and stored on-site by large tanks or impoundments (GWPC and ALL Consulting 2009). Because ground and surface water are hydraulically connected, changes in the quantity and quality to one likely influence the other (Winter et al. 1998).

In the northeastern US, shale formations (e.g., Devonian, Marcellus, and Utica) underlie a number of sensitive watersheds, such as the upper Delaware River, a designated Wild and Scenic River that supplies drinking water to >15 million people. Stakeholder concerns include the high rate of water removal from small streams at the headwaters of these watersheds (Maclin et al. 2009, Myers 2009). Withdrawals of large quantities of water at these locations can significantly affect the hydrology and hydrodynamics of surface water resources. Changes in water depth can alter the flow regime, velocity, and temperature of springs, streams and lakes, affecting *in situ* flora and fauna (Zorn et al. 2008). Additionally, removal of significant volumes of water can reduce the dilution effect and increase the concentration of contaminants in surface water (Pennsylvania State University 2010).

Ground water resources (e.g., aquifers) also are tapped for HVHF operations. Rapid withdrawal from aquifers can lower the water table levels, changing water quality by exposing naturally occurring minerals to an oxygen-rich environment, potentially causing chemical changes that alter mineral solubility and mobility, leading to salination of water and other chemical contaminations. Lower water tables also may cause upwelling of lower quality water and other substances (e.g., methane) from deeper within an aquifer and could lead to subsidence or destabilization of the local geology. (USEPA 2011)

Water contamination and toxic exposures. In addition to water, HVHF fluids typically include a combination of additives that serve as friction reducers, cross-linkers, breakers, surfactants, biocides, pH adjusters, scale inhibitors, and gelling agents (New York State Department of Environmental Conservation [NYSDEC] 2010). The goal is to achieve an ideal

viscosity that encourages fracturing of the shale and improves gas flow, while discouraging microbial growth and corrosion which can inhibit recovery efficiency (US Department of Energy [USDOE] 2009). The percentage of chemical additives in a typical HVHF operation is <0.5% by volume but can reach as high as 2% by volume (Soeder and Kappel 2009, NYSDEC 2011). Thus, an HVHF operation using 5 million gallons of water can use 25,000 to 100,000 gallons of chemical additives. The types and concentrations of chemical additive and proppants vary depending on conditions of the specific well being fractured, and companies typically create fracturing fluid tailored to the specifics of the formation and needs of the project (USEPA 2011). The New York State Department of Conservation (2011) lists chemicals proposed for use in the state by shale gas developers, including 235 products in hydraulic fracturing fluids, containing 322 unique chemicals and at least 21 additional compounds.

In 2011, the US House of Representatives Committee on Energy and Commerce launched an investigation examining HVHF practices. The Committee found that "between 2005 and 2009, 14 oil and gas service companies used more than 2,500 additives, containing 750 chemicals and other components", including "29 chemicals that are: (1) known or possible human carcinogens; (2) regulated under the Safe Drinking Water Act for their risks to human health; or (3) listed as hazardous air pollutants under the Clean Air Act" (Waxman 2011). The Committee revealed that over the 4-year period these additives included lead, ethylene glycol, benzene, toluene, and xylene compounds. Moreover, the investigation reported that over 32 million gallons of diesel fuel, one of the only additives regulated by the Safe Drinking Water Act, were injected across nineteen states.

Wastewater is generated during the HVHF process in the form of flowback (i.e., fluid returned to the surface after HVHF has occurred, but before the well is placed into production) and produced water (i.e., the fluid returned after the well is placed into production) (USEPA 2011). During injection, HVHF fluids come in contact with the bedrock, often affecting the mobility of naturally occurring substances in the subsurface, particularly in the hydrocarbon-containing formation. These substances include formation fluids (e.g., brine or sodium chloride; Piggot and Elsworth 1996), gases (e.g., methane, ethane, carbon dioxide, hydrogen sulfide; Zoback et al. 2010), trace elements (e.g., mercury, lead, arsenic; Harper 2008, Leventhal and Hosterman 1982, Tuttle et al. 2009, Vejahati et al. 2010), naturally occurring radioactive material (e.g., radium, thorium, uranium: Leventhal and Hosterman 1982, Harper 2008, Tuttle et al. 2009, Vejahati et al. 2010) and organic material (e.g., acids, polycyclic aromatic hydrocarbons, benzene, toluene, xylene; URS Corporation 2009, NYSDEC 2011). Some of these substances may be liberated from the formation via complex biogeochemical reactions with the chemical additives found in hydraulic fracturing fluid (Long and Angino 1982, Falk et al. 2006). New York tested flowback from Marcellus Shale gas production in Pennsylvania and West Virginia and found 154 chemicals, many of which are health hazards and are regulated via primary and secondary drinking water standards (NYSDEC 2011). A list of chemicals identified in flowback and produce water is presented in USEPA (2011; Table E2).

Estimates for recovery of fracturing fluid in flowback for the Marcellus Shale range from 10–30% (Arthur et al. 2008). The physical and chemical properties of wastewater vary with fracturing fluid, geographic location, geology and time (Veil et al. 2004, Zielinski and Budahn 2007, Zoback et al. 2010, Rowan et al. 2011). During or prior to treatment, flowback and produced water often are retained on-site in storage tanks, open-air impoundments or evaporation ponds (GWPC and ALL Corporation 2009). Later, these fluids are transported to treatment facilities, injected underground, or discharged to waterways and the environment. Underground injection is the primary method of wastewater disposal from all major plays, except for the Marcellus Shale (Horn 2009, Veil 2007, 2010). For some operations, fluids are transported to wastewater treatment at publicly-owned treatment works or commercial wastewater treatment facilities. However, few facilities are capable of treating fluids containing dangerous contaminants (e.g., radioactive materials), brine (high salinity fluids), and unique compounds, which often are expensive to remove, generated by HVHF operations (Veil 2010, US General Accounting Office [USGAO] 2012).

Contamination from wastewater can occur at any time during operations. Large HVHF operations require extensive quantities of supplies, equipment, and vehicles, which may increase the risks of accidental releases, such as spills or leaks. Surface spills or releases can occur as a result of tank ruptures, impoundment failures, overfills, vandalism, accidents, or improper operations. Released fluids also may flow into nearby surface water bodies or infiltrate into the soil and near-surface groundwater (NYSDEC 2011). Entrekin et al. (2011) reported that 80% of Marcellus Shale gas wells are located within 200 m of riparian areas and 100% are within 300 m. Regulating the rapid expansion of HVHF operations is problematic and violations are common (Entrekin et al. 2011). For example, between January 2008 and December 2011 a total of 3,355 violations of environmental laws by 64 different Marcellus Shale gas drilling companies were reported by the Pennsylvania Department of Environmental Protection. Of these, 2,392 violations of these that likely posed a direct threat to our environment and were not reporting or paperwork violations (Staaf 2012).

The ability of naturally occurring but toxic substances or fracturing fluids to reach ground or surface waters is possible if fractures extend beyond the target formation and reach aquifers, or the casing or cement around wells fails causing contaminants to migrate into drinking water (USEPA 2011). Contamination also can occur through mismanagement and improper operating procedures, inadequate waste treatment practices, improper storage, or inadequately constructed impoundments or well casings. Occurrences of improper well construction and operation, allowing subsurface pathways for contaminant migration resulting in water pollution have been reported (State of Colorado Oil and Gas Conservation Commission 2009a, b, c, PADEP 2010, USAEPA 2010, McMahon et al. 2011). A study in the Marcellus Shale region concluded that methane gas was seventeen times higher in water wells closer to natural gas wells. (Osborne et al. 2011). The concentration of methane in these wells fell within the defined action level for hazard mitigation recommended by the US Office of the Interior (Eltschlager et al. 2001).

Sub-lethal impacts of shale gas development also may adversely influence aquatic environments and interfere with ecological interactions, such as whole-stream metabolism, decomposition of organic matter and accrual of macro-invertebrate biomass (Evans-White and Lamerti 2009). Land clearing during well pad and infrastructure (e.g., roads and pipelines) development, and increased road traffic throughout operations can increase sediment runoff into adjacent streams, lakes and wetlands (Williams et al. 2008, Entrekin et al. 2011). Excessive sediment in aquatic habitats results in higher levels of suspended and benthic particles, which may reduce stream flow, alter light, temperature, dissolved oxygen, and pH levels, and degrade spawning habitat for macro-invertebrate insects (Wood and Armitage 1999, Williams et al. 2008). Reductions in feeding efficiencies or the availability and abundance of prey can lead to negative effects on reproduction and growth of higher trophic-level animals (Peckarsky 1984, Sandheinrich and Atchison 1989, Burkhead and Jelks 2001). Moreover the introduction of chemicals associated with shale gas development (i.e., HVHF fluids and wastewater) can lead to a decline in production by eliminating sensitive taxa representing a majority of community growth and or biomass (Woodcock and Huryn 2007).

Habitat loss and degradation. Habitat loss or degradation is commonly associated with anthropogenic activities, including those of the oil and gas industry. Historically, with vertical drilling, one well pad equaled one well, but horizontal drilling allows for multiple wells per well pad (GWPC and ALL Consulting 2009). However, with the rapid expansion of this energy sector, hundreds of thousands of well sites are projected over the next twenty years, many of which are slated for forest habitat. For Marcellus Shale operations in Pennsylvania, an average, 8.8 acres (3.6 hectares [ha]) of habitat are required for each well pad and associated infrastructure (e.g., storage areas, roads and pipeline corridors) (Johnson 2010). The cumulative impact of all operations in a region can result in landscape level changes in habitat. For example, the projected number of wells by 2030 in Pennsylvania alone ranges from 6,000 to 15,000 (Johnson 2010). Given that nearly two thirds of these wells are expected to occur on forest lands, the potential area of forest to be cleared varies from 33,800 acres (13,800 ha) to 83,000 acres (32,700 ha). Additional habitat loss is likely as other formations, such as the Utica Shale, are developed.

Damage to forest habitat can occur from mechanical clearing during site development and from mismanagement of wastewater. At the US Forest Service Fernow Experimental Forest, damage to over two dozen trees and ground vegetation adjacent to a well pad occurred when HF fluid escaped the well bore during drilling (Adams et al. 2011). The release of fluid drifted over the immediate area causing browning of foliage and loss of leaves and ground vegetation. A major component of the HF fluid, and likely cause of damage, at this site was hydrochloric acid (15% by volume). Subsequent to this accident, fluids were experimentally applied to forest patches. Temporal and spatial development of the applications suggested that direct contact and uptake from the soil by the roots resulted in detrimental effects. A total of 147 trees (11 species)

were affected. The application resulted in a much more open canopy than either control or recently burned plots, resulting in significantly more light penetration.

Removal of forest habitat, regardless of method, creates an associated edge effect ranging from 100–300 m into the interior forest stand. Increasing light and wind exposure, and changing temperature can alter vegetation dynamics, causing avoidance by many birds, mammals, reptiles and amphibians (Gibbs 1998, Flashpohler et al. 2001, Marsh and Beckman 2004). Disturbed areas also are more vulnerable to invasive plants (Meeking and McCarthy 2001, Harper et al. 2005). Furthermore, the distribution of clearings will increase forest fragmentation, resulting in species isolation and loss of genetic diversity (Lee et al. 2011). In Pennsylvania, Johnson (2010) estimated an additional 21 acres (8.6 ha) of interior forest habitat would be affected for every 8.8 acres (3.6 ha) of cleared forest for Marcellus Shale development. Thus, a total of direct and indirect impacts to forest habitat could equal 30 acres (12.3 ha) per well pad, resulting in 81,500 to 200,300 acres (33,340–81,940 ha) of forest habitat loss or degradation (Johnson 2010). Drohan et al. (2012) indicated this level of impact was enough to substantially alter the Pennsylvania landscape.

Greenhouse gas emissions. During combustion, natural gas emits less carbon dioxide (a greenhouse gas [GHG]), nitrogen oxide and sulfur oxide (two contaminants contributing to acid rain) than coal (Entrekin et al. 2011). However, during extraction, shale gas development produces considerable amounts of methane, a major component of natural gas and a powerful GHG (Howarth et al. 2011). The amount of fugitive emissions of methane into the atmosphere during HVHF operations compared to conventional operations may contribute more to global warming than other fossil fuel development (USEPA 2010). Howarth et al. (2011) calculate that during the life cycle of an average shale gas well, 3.6–7.9% of the total production of the well is emitted to the atmosphere as methane, which is at least 30% to 50% as great as estimated for a conventional well. Methane dominates the GHG footprint for shale gas on a 20-yr time horizon, contributing 1.4–3 times more than does carbon dioxide emission, resulting in a GHG footprint for shale gas at 22%–43% greater than that for conventional gas.

POTENTIAL IMPACTS TO BATS

Bats of the northeastern US are insectivorous and are the primary consumers of nocturnal arthropods, including many agricultural and forest pests. Given the relatively large volumes of insects consumed (up to 100% of bats body mass/night; Kurta et al. 1989) and extensive foraging home ranges, bats play a major role in suppressing nocturnal insect populations and transporting nutrients across landscapes (Fenton 2003, Jones et al. 2009). Moreover, bats provide an economic benefit by saving US farmers an estimated $22.9 billion (range: $3.7–$53 billion) each year in pesticide use (Boyles et al. 2011). Because of their important role in ecosystem services, bats often are used as indicators of habitat quality (Wickramasinghe et al. 2003, Kalcounis-Rupell et al. 2007, Jones et al. 2009). Bats may serve as the proverbial “canary in the coalmine” because many of their life history traits make them sensitive to human-induced environmental

changes (Estrada et al. 1993, Medellin et al. 2000, Moreno and Halffler 2000, 2001, Estrada and Coates-Estrada 2001a, b, Clarke et al. 2005a, b, Hayes and Loeb 2007, Kunz et al. 2007). Bats have low reproductive potential (i.e., reproducing once per year and typically only having a single pup) and require high adult survivorship to avoid population declines (Barclay and Harder 2003, Podlutsky et al. 2005). Because bats are not able to recover quickly, large-scale changes may put populations at risk (Findley 1993, Henderson et al. 2008).

Historically, contamination from pesticide use and loss or disturbance of suitable habitat contributed to population declines. In recent years, both anthropogenic and natural forces have adversely affected North American bats, particularly in the northeast. Since 2003, wind energy development has resulted in potentially hundreds of thousands of bat fatalities (Kunz et al. 2007, Arnett et al. 2008). Although wind-powered turbines primarily affect migratory tree-roosting bats, cave-roosting species (e.g., little brown bat [*Myotis lucifugus*] and tri-colored bat [*Perimyotis subflavus*]) can compose approximately 20% of fatalities (Arnett et al. 2008). In 2006, the first fatalities from White-nose Syndrome (WNS) were documented in New York. Over the past six years, the fungus (*Geomyces destructans)* causing WNS has spread across nineteen states and killed millions of bats from six different species (Bat Conservation International; www.batcon.org). Little brown bats, once considered common, have shown the greatest mortality of all species affected by WNS (Frick et al. 2010b), but northern long-eared (*M. septentrionalis*), eastern small-footed (*M. leibii*), Indiana (*M. sodalis*), and tricolored bats also have experienced severe mortality (Kunz and Reichard 2011). Turner et al. (2011) estimated an 88% decrease in the total number of hibernating bats, with 98%, 91% and 72% declines in hibernating northern long-eared, little brown bats, and Indiana bats, respectively.

The perilous decline in bat populations is exacerbated by the additive nature of both WNS and numerous anthropogenic activities, possibly including shale gas development (USGS 2009). Coincidentally, the Marcellus Shale lies within the same area as the epicenter of WNS. The impacts associated with natural gas exploration and extraction in this region may further imperil already decimated bat populations (Matteson 2010). Of particular concern are the Indiana bat, currently listed under the Endangered Species Act, the northern long-eared and eastern small-footed, recently petitioned for listing by the Center for Biological Diversity (Matteson 2010), and the little brown bat, a species predicted to be extirpated from a significant proportion of its range by 2026 (Frick et al. 2010b, Kunz and Reichard 2011). Although there are no publicly available studies investigating the impacts of shale gas development on bats, we can infer potentially adverse effects based on other human-induced landscape-level changes.

Water withdrawal. Aquatic habitats play a critical role in the ecology of bats, both as sources of water and insect prey (Racey and Swift 1985, Grindal et al. 1999, Downs and Racey 2006, Hayes and Loeb 2007). Bats have relatively high rates of evaporative water loss, and must obtain much of their intake from available surface water resources (Kurta et al. 1989, 1990, McClean and Speakman 1999, Webb 1995, Neuweiler 2000). Kurta et al. (1989) estimated that bats may drink up to 26% of their daily water intake from open water sources (e.g., ponds or

streams) to maintain water balance. Available water is vital for reproductively active females, particularly lactating bats, which require a sufficient amount of water while nursing young (Johnson et al. 2011). Adams and Hayes (2008) observed lactating female bats drinking 13 times more often than non-reproductive bats. Moreover, studies have shown that pregnant and lactating female bats select foraging areas, in part, based on proximity to water (Speakman et al.1991, McClean and Speakman 1999, Adams and Thibault 2006). For example, Johnson et al. (2011) observed eastern small-footed bat roosts within 500 m from water sources.

Riparian areas and other hydric habitats (e.g., lakes, ponds, and wetlands) are important resources because they support higher concentrations of nocturnal insects (MacGregor and Kiser 1998). Many bat species are opportunistic foragers and select areas where abundant and available prey occur (Thomas 1988, Barclay 1991, Barclay and Brigham 1991, Hart et al. 1993, Krusic and Neefus 1996, Grindal et al. 1999, Broders 2003). Murray and Kurta (2002) found that aquatic insects compose a large proportion of the diets of Indiana bats in the northern part of the species range. Commuting and foraging activity for many species is typically higher in riparian areas than in upland sites (Furlonger et al. 1987, Krusic et al. 1996, Grindal et al. 1999, Zimmerman and Glanz 2000, Seidman and Zabel 2001, Veilleux et al. 2003, Leput 2004, Menzel et al. 2005) and some species spend significant proportions of their nightly activity in these areas (LaVal et al. 1977, Brigham et al. 1992, Barclay 1999, Fellars and Pierson 2001, Waldien and Hayes 2001). Thus, the extensive withdrawal of water resources from the environment, particularly in sensitive areas or areas under drought conditions, will presumably affect roost-site selection and abundance and availability of prey.

Water contamination and toxic exposures. Riparian habitats support large numbers of insects and are prime foraging areas for insectivorous bats (Vaughn et al. 1996,). However, the inflow of heavy metals and other toxins from industrial wastes can adversely affect water quality and the invertebrate community (Mason 1997, Jones et al. 2009). Bats have been observed congregating and drinking from holding ponds at industrial sites (Huie 2002). Clark and Hothem (1991) reported the occurrence of bats dying by asphyxiation after drinking solutions containing cyanide from open holding ponds of gold mining operations. Similarly, open pits containing flowback and produced water associated with HVHF operations could expose bats to toxins, radioactive material and other contaminants.

Exposure to environmental contaminants is a suspected factor in the decline of North American bat species (US Fish and Wildlife Service [USFWS] 1999, Schmidt et al. 2002). Metabolic processes of insectivorous bats are rapid and bats consume large quantities of food relative to their body mass (Kurta et al. 1989, Schmidt et al. 2002). Because dietary accumulation and metabolic capacity increase at higher trophic levels, and because insectivorous bats are apex predators, bats are likely more susceptible to contaminants (Allerya et al. 2000, Eisler and Wiemeyer 2004, Jones et al. 2009). Toxic contamination can occur during normal operations, accidentally or by improper management. In such an event, contaminated drilling mud or water may migrate into caves and fissures used by bats, which can be ingested by

grooming or be inhaled (Adams et al. 2011). Toxins often accumulate in fat, and are more likely to have adverse physiological effects when bats are depleting fat reserves, such as during hibernation, migration, or lactation (Kurta et al. 1989, O'Shea and Clark 2002).

Three heavy metals, cadmium, mercury, and lead, commonly associated toxins in wildlife studies, are contaminants reported in HVHF operations. Cadmium affects a number of systems, including reproductive and renal systems (Chmielnicka et al. 1989, Walker et al. 2007). A paucity of information exists on the occurrence and affect on cadmium in bats. However, Clark et al. (1988) postulated a relationship between cadmium concentrations in the guano of grey bats (*M. grisescens*), a federally endangered species, and kidney lesions. Mercury concentrations in aquatic and terrestrial food webs of the northeastern US are considered detrimental to local bat populations (Driscoll 2007, Osborne et al. 2011). Observed consequences of mercury exposure in mammals include reduced immune function, hormonal changes, impaired function of the central nervous system and motor skill impairment, and reduced reproductive success (Wiener and Spry 1996, Nocera and Taylor 1998, Evers et al. 2004, Schweiger et al. 2006). Lead is the most ubiquitous toxic metal and has been associated with a wide range of toxic effects from neurological, hematological, renal, and reproductive (Goyer 1996). Several studies have reported the potential negative impacts of lead on both wild and captive bats (Zook et al. 1970, Sutton and Wilson 1983, Hariono et al. 1993, Skerratt et al. 1998, Walker et al. 2007), including a possible link between elevated concentrations of lead and still births in big brown and little brown bats (Clark 1979).

Data on the impacts of other toxins and radionuclides on bats is limited (Eisher 1994, Ma and Talmage 2001, O'Shea and Clark 2002). The majority of data on bats and environmental contaminants comes from studies investigating the impacts of pesticides, and, to a lesser extent, heavy metals (O'Shea and Clark 2002, Schmidt et al. 2002). However, if contaminants associated with HVHF operations are introduced into aquatic ecosystems and are readily transferrable through insectivorous food chains, bats will presumably accumulate these substances and potentially suffer adverse effects.

Habitat loss and degradation. Fragmentation is considered a primary threat to global biodiversity (Franklin et al. 2002) and has the potential to directly impact bat populations by limiting essential roosting and foraging resources (Fenton 2003, Safi and Kerth 2004, Lane et al. 2006, Henderson et al. 2008). Anthropogenic changes in ecosystems often result in fragmenting forest landscapes and typically occur at rates dramatically faster than long-lived organisms are capable of adapting, thus disrupting life history cycles and ecological processes (Duchamp and Swihart 2008). Rapid ecosystem changes are associated with population declines in many bat species (Jones et al. 2009, Safi and Kerth 2004). In North America, the result of human-induced changes often results in patchy species distributions rather than range contraction (Pierson 1998). Recent studies have focused on temperate bat communities in greatly modified ecosystems, finding a positive association between bat abundance and diversity, and remnant natural habitat, such as forests and wetlands (Walsh and Harris 1996, Jaberg and Guisan 2001, Russ and

Montgomery 2002, Gehrt and Chelsvig 2004, Duchamp and Swihart 2008). Negative effects on bats from forest cover loss also are well documented from processes such as forest harvesting (Grindal 1996, Patriquin and Barclay 2003) urban expansion (Evelyn et al. 2003, Duchamp et al. 2004, Sparkes et al. 2005a) and agricultural intensification (Russ and Montgomery 2002, Lesinski et al. 2007).

Intact, mature forest stands possess structural features such as snags and large, overstory trees that are vital for cavity- and foliage-roosting bats, respectively (Jung et al. 1999, Cryan et al. 2001, Carter and Feldhamer 2005, Broders et al. 2006, Perry and Thill 2007, O'Keefe et al. 2009). In summer, bats select specific structures that offer protection and appropriate thermoregulatory conditions for survival and development of young (Humphrey et al. 1977). Loss of forest cover and degradation of forested habitats have been cited as part of the decline of Indiana bats (USFWS 1983, Gardner et al. 1990, Garner and Gardner 1992, Drobney and Clawson 1995, Whitaker and Brack 2002). Presence of northern long-eared bats, an interior forest species, is dependent on mature, contiguous deciduous forests for both roosting and foraging habitat (Sasse and Perkins 1996, Hutchinson and Lacki 2000, Lacki and Schwierhojan 2001, Broders and Forbes 2004, Carter and Feldhamer 2005, Broders et al. 2006, Perry et al. 2007, Henderson and Broders 2008). Moreover, this species forages almost exclusively in closed canopy forests and avoids forest gaps and open areas (Owen et al. 2003, Patriquin and Barclay 2003, Schirmacher et al. 2009).

Many forest-dwelling bats frequently switch roosts (Lewis 1995), but tend to remain loyal to specific roosting and foraging areas. Site fidelity is advantageous, allowing bats to become familiar with suitable roost trees and the local spatio-temporal variation in prey abundance and availability, thus decreasing time spent commuting and foraging (Avital and Jablonka 2000, Broders et al. 2006). Studies of Indiana bat roost-site selection show reproductively active females returning to the same home range year after year to establish maternity colonies. (Humphrey et al. 1977, Gardner et al. 1991a, 1991b, Gardner et al. 1996, Callahan et al. 1997, Menzel et al. 2001, Kurta and Murray 2002, Britzke et al. 2003, Whitaker and Sparks 2003, Whitaker et al. 2004). Roost tree reoccupation of up to six years has been documented in a number of studies (Garner et al. 1991b, Whitaker et al. 2004, Barclay and Kurta 2007). Maternity colonies of Indiana bats also appear to be faithful to their foraging areas within and between years (Cope et al. 1974, Humphrey et al. 1977, Gardner et al. 1991a, 1991b, Murray and Kurta 2004, Sparks et al. 2005b). Similarly, northeastern long-eared, eastern small-footed, and tri-colored bats select specific areas, often re-using sites within and among years (Kalcounis and Hecker 1996, Sasse and Pekins 1996, Brigham et al. 1997, O'Donnell and Sedgley 1999, Weller and Zabel 2001, Menzel et al. 2002, Willis and Brigham 2004, Perry and Thill 2007).

The philopatry observed among numerous species requires consideration by natural resource managers who often permit harvesting trees during winter when bats are hibernating, a practice intended to limit directly harmful effects of development (Arnold 2007). However, because females consistently return to the same site(s), this practice may do less to mitigate the

immediate effects of habitat loss than anticipated. Bats, already pregnant, arrive to sites after hibernating for seven months and migrating for up to 500 kilometers (km), at a time of cool, wet weather, which likely limits prey availability (Humphrey et al. 1977, Kurta et al. 1996, Murray 1999). The loss or alteration of forest habitat places additional stress on females, and may increase thermoregulatory costs and potentially disrupt social bonds of a colony (Kurta and Murray 2002). Such impacts have been documented in other bat species. Brigham and Fenton (1986) documented a 56% decline in reproductive success of a big brown bat colony that was excluded from their maternity roost. Sparks et al. (2003), demonstrated that the natural loss of a single primary maternity roost lead to fragmentation of the colony (bats used more roosts and congregated less) the following year after roost loss.

Hibernacula and the habitat surrounding these sites also warrant protection from development, particularly drilling operations. Hibernating bats select sites within caves and mines possessing specific microclimate (e.g., temperature, humidity, and airflow) conditions (Clawson et al. 1980, Tuttle and Kennedy 2002). Alterations to this microclimate, whether natural or human-induced, often render a site less suitable for hibernation (Johnson et al. 2002). Moreover, disturbing bats during winter hibernation may result in additional arousals causing bats to lose fat reserves and possibly abandon the roost. Adams et al. (2011) highlighted the importance of understanding the connectivity of karst geology in proximity to winter hibernacula prior to development. Modifications to the surface habitat surrounding hibernacula also can contribute to changes in microclimate conditions, as well as influence the suitability of foraging characteristics. The landscape surrounding hibernacula supports foraging and roosting needs of large numbers of bats during fall swarming periods, when bats are building up crucial fat reserves to survive the winter (Hall 1962). Areas surrounding hibernacula also provide important summer habitat for male Indiana bats that do not migrate far from the winter roost.

Habitat use by forest bats is complex and varies by species. Bats rely on extensive resources over large areas (Duchamp et al. 2009). The magnitude of shale gas development predicted over the next twenty years is expected to have similar effects on forest landscapes (i.e., habitat loss and degradations) as other anthropogenic activities, but at a much greater level due to the proliferation of projected drilling sites. Therefore, providing conditions necessary to support bat populations will require a combination of designating certain forest areas as off-limits and implementing forest management practices that perpetuate suitable roosting and foraging habitat (Duchamp et al. 2009).

Greenhouse gas emissions. The effects of climate change on bats have not been studied extensively. However, it is believed that insectivorous bats may be among the most affected species because seasonal temperature changes may affect hibernation, food abundance and availability, and recruitment (Jones et al. 2009). Most bat species have specific temperature regimes that are conducive for surviving over half the year in hibernation. For example, Indiana bats hibernate in caves or mines where the ambient temperature is consistently below 10° C (Hall 1962, Meyers 1964, Henshaw 1965, Humphrey 1978, Tuttle and Kennedy 2002). Tuttle and

Kennedy (2002) reported that populations hibernating with temperatures between 3–7.2° C remained stable or increased, whereas populations hibernating at temperatures above or below this range were unstable or declined. With winter conditions expected to become shorter and warmer, disruptions to the mammalian overwintering energy budgets are expected (Gu et al. 2008). Milder winter conditions may force bats to enter hibernacula later than usual, presumably with inadequate fat reserves if food availability decreases in late fall (Matteson 2010). Warmer temperatures in winter also may result in unsustainable arousal frequencies (Humphries et al. 2002). Because arousals account for up to 80% of the energy budget (Thomas 1995) of hibernating bats, any increase in frequency or duration could decrease survivorship.

It has also been posited that changes in temperature may disrupt bat reproductive physiology. In winter, altered temperature regimes may diminish the viability of spermatozoa stored in the female reproductive tract, thus females may not become pregnant upon emergence, or become pregnant too early and undergo embryonic development and parturition earlier in the spring, which may lead to declining recruitment if conditions are not suitable for young (Jones et al. 2009). In summer, dwindling water resources caused by warmer temperatures and reduced precipitation can lead to lower reproductive rates as female are not able to meet their water budget to produce milk for nursing pups (Kurta and Rice 2002, Barclay et al. 2004, Adams and Hayes 2008, Rodenhouse et al. 2009). Adams (2010) observed reductions in reproductive behavior and increases in non-reproductive female bats in years with above average temperature and below average precipitation, conditions similar to predictions of regional climate warming and increased drought.

Changes in precipitation and temperature also are anticipated, thus diminishing water availability during summer and altering the distribution, abundance, and phenology of insects (Hughes 2000, Bale et al. 2002, Parmesan 2003, Menendez 2007, Rodenhouse et al. 2009). Reductions in insect abundance and availability will have detrimental effects on bat populations, particularly during critical periods (i.e., during pregnancy, lactation and fall swarming). Frick et al. (2010a) concluded a direct relationship between cumulative summer precipitation and probability of survivorship in little brown bats.

Climate data indicates we are in a rapid period of change, which already is being observed across a range of ecosystems (Jones et al. 2009). Climate change is likely to affect roosting and foraging behaviors and opportunities, particularly during times when bats are most vulnerable. Anthropogenic activities that increase the global GHG footprint, including HVHF operations, presumably will exacerbate adverse impacts on bat populations. Thus, methods to reduce the fugitive emissions of methane from shale gas development should be explored and implemented.

CONCLUSIONS

Bats are vital in terms of their ecological and economic roles, and are well suited as indicators of environmental health (Fenton 2003, Jones et al. 2009). Worldwide, bats function as pollinators, seed dispersers, and biological controls for nocturnal insects (Kunz and Parsons 2009). In North America, most species are insectivorous and consume large quantities of night-flying insects, many of which are agricultural and forest pests. Regrettably, many bat species are experiencing population declines and range contraction in response to both natural and human-induced environmental stressors (Jones et al. 2009). White-nose Syndrome has decimated hibernating bat populations in northeastern North America, including declines of nearly 98% and 88% in Pennsylvania and New York, respectively (Turner et al. 2011). Species affected include the little brown bat, a once common species, and the federally endangered Indiana bat (Frick et al. 2010b). At least three additional species are being considered for listing (Matteson 2010 Kunz and Reichard 2011). A sense of urgency exists among bat biologists because bats have low reproductive rates and respond slowly to rapid population declines (Barclay and Harder 2005). Compounding the devastation of White-nose Syndrome are human activities associated with the degradation and destruction of suitable habitat and resources for these imperiled species (Kunz and Parsons 2009). As with other industrial practices, shale gas development contributes to water withdrawal and contamination, habitat loss and degradation, and the emission of GHGs resulting in detrimental effects on bat populations and their environment. Immediate action is required to reduce these adverse impacts and to ensure that bats and the ecosystems they serve are considered during shale gas development and production.

Eastern small-footed bat (*Myotis leibii*). Photo credit: Bat Conservation International.

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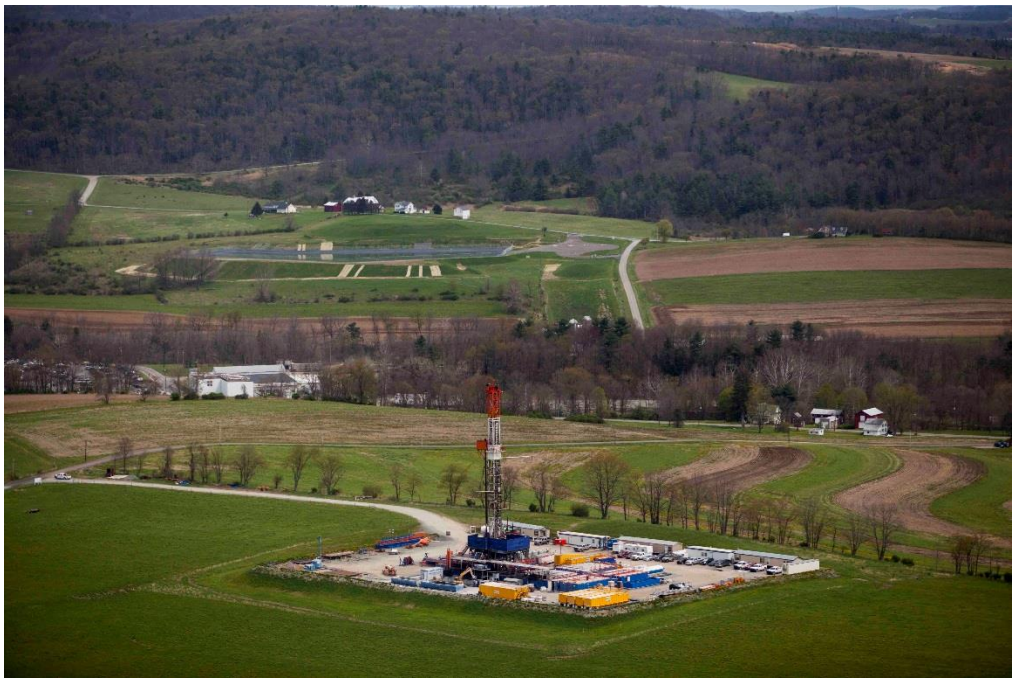
Concerned Health Professionals of NY

COMPENDIUM OF SCIENTIFIC, MEDICAL, AND MEDIA FINDINGS DEMONSTRATING RISKS AND HARMS OF FRACKING (UNCONVENTIONAL GAS AND OIL EXTRACTION)

July 10, 2014



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Introduction

Horizontal drilling combined with high-volume hydraulic fracturing and clustered multi-well pads are recently combined technologies for extracting oil and natural gas from shale bedrock. As this unconventional extraction method (collectively known as "fracking") has pushed into more densely populated areas of the United States, and as fracking operations have increased in frequency and intensity, a significant body of evidence has emerged to demonstrate that these activities are inherently dangerous to people and their communities. Risks include adverse impacts on water, air, agriculture, public health and safety, property values, climate stability and economic vitality.

Researching these complex, large-scale industrialized activities—and the ancillary infrastructure that supports them—takes time and has been hindered by institutional secrecy. Nonetheless, research is gradually catching up to the last decade's surge in unconventional oil and gas extraction from shale. A growing body of peer-reviewed studies, accident reports, and investigative articles is now confirming specific, quantifiable evidence of harm and has revealed fundamental problems with the drilling and fracking. Industry studies as well as independent analyses indicate inherent engineering problems including well casing and cement impairments that cannot be prevented. Earlier scientific predictions and anecdotal evidence are now bolstered by empirical data, confirming that the public health risks from unconventional gas and oil extraction are real, the range of adverse impacts significant, and the negative economic consequences considerable. Our examination of the peer-reviewed medical and public health literature uncovered no evidence that fracking can be practiced in a manner that does not threaten human health.

Despite this emerging body of knowledge, industry secrecy and government inaction continue to thwart scientific inquiry, leaving many potential problems—especially cumulative, long-term risks—unidentified, unmonitored and largely unexplored. This problem is compounded by non-disclosure agreements, sealed court records, and legal settlements that prevent families (and their doctors) from discussing injuries. As a result, no comprehensive inventory of human hazards yet exists.

At the same time, inflated estimates of shale reserves and potential profitability continue to fuel the rush to drill new wells, cut regulatory corners, and press into densely populated communities, as corporations attempt to compensate for the unexpectedly rapid depletion of their existing wells and coincident drop off in revenue. Thus do the fundamental economic uncertainties of shale gas and oil production further exacerbate the risks of fracking to public health and society. With the industry intention of drilling tens of thousands of new wells into shale every year in the United States and with more than 15 million Americans already living within a mile of a fracking well that has been drilled since 2000, the stakes could not be higher.

About This Report

The Compendium is a fully referenced compilation of the significant body of scientific, medical and journalistic findings demonstrating risks and harms of fracking. Organized to be accessible to public officials, researchers, journalists and the public at large, the Compendium succinctly summarizes key studies and other findings relevant to the ongoing public debate about unconventional methods of oil and gas extraction. The Compendium should be used by readers to grasp the scope of the information about both public health and safety concerns and the economic realities of fracking that frame these concerns. The reader who wants to delve deeper may consult the reviews, studies, and articles referenced. (In addition, a fully searchable, near-exhaustive citation database of peer-reviewed journal articles pertaining to shale gas and oil extraction is housed at the PSE Healthy Energy Library.[1])

[1] Physicians Scientists & Engineers for Health Energy. http://www.psehealthyenergy.org/site/view/1180).

The pace at which new studies and information are emerging has rapidly accelerated in the past year and a half: the first few months of 2014 saw more studies published on the health effects of fracking than all studies published in 2011 and 2012 combined.[2] In accordance, the Compendium is organized in reverse chronological order, with the most recent information first.

Fifteen compelling themes emerged in reviewing the data, and these serve as the organizational structure of the Compendium. The document opens with sections on two of the most acute threats—air pollution and water contamination—and ends with medical and scientific calls for more study and transparency. Readers will quickly notice the recent upsurge in studies making each section top-heavy with recent data.

The Compendium focuses on topics most closely related to the public health and safety impacts of unconventional gas and oil drilling and fracking. Many additional risks and harms arise from associated infrastructure and industrial activities that necessarily accompany drilling and fracking operations. These include pipelines, compressor stations, oil trains, sand mining operations, cryogenic and liquefaction facilities, processing and fractionation complexes, import/export terminals, and so forth. While impacts from infrastructure are critically important to public health and safety and while the Compendium refers to these impacts in certain instances when studies covered have also addressed them, a detailed accounting of these ancillary impacts are not included in this document.

Given the quickly expanding body of evidence, the Compendium will be revised and updated approximately every six months. It is a living document, housed on the Concerned Health Professionals of New York website, and serves as an educational tool in the public and policy dialogue. The studies cited in this first edition are current through June 30, 2014.

The Compendium was not a funded project; it was written utilizing the benefit of expertise and experiences of numerous health professionals and scientists who have been involved in this issue for years.

We welcome your feedback and comments.

About Concerned Health Professionals of New York

Concerned Health Professionals of New York (CHPNY) is an initiative by health professionals, scientists and medical organizations for raising science-based concerns about the impacts of fracking on public health and safety. CHPNY provides educational resources and works to ensure that careful consideration of the science and health impacts are at the forefront of the fracking debate. http://concernedhealthny.org

[2] Mobbs, P. (2014). Shale gas and public health - the whitewash exposed. *The Ecologist*. Retrieved July 3, 2014, from http://www.theecologist.org/News/news_analysis/2385900/shale_gas_and_public_health_the_whitewash_exposed.html

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*Note that for the purposes of this compendium, the terms "fracking" and "drilling and fracking" refer to the entire unconventional oil and gas extraction and distribution process, from well site preparation to waste disposal and all associated infrastructure including pipelines and compressor stations. Not every aspect of this process is fully addressed in the Compendium.

Executive Summary

Evidence of risks, harms, and associated trends demonstrated by this Compendium:

- **Air pollution** – Studies increasingly show that air pollution associated with drilling and fracking operations is a grave concern with a range of impacts. Researchers have documented dozens of air pollutants from drilling and fracking operations that pose serious health hazards. Areas with substantial drilling and fracking build-out show high levels of ozone, striking declines in air quality, and, in several cases, increased rates of health problems with known links to air pollution.

- **Water contamination** – The emerging science has significantly strengthened the case that drilling and fracking inherently threaten groundwater. A range of studies from across the United States present strong evidence that groundwater contamination occurs and is

more likely to occur close to drilling sites. Likewise, the number of well blowouts, spills and cases of surface water contamination has steadily grown. Meanwhile, the gas industry's use of "gag orders," non-disclosure agreements and settlements impede scientific study and stifle public awareness of the extent of these problems.

- **Inherent engineering problems that worsen with time** – Studies and emerging data consistently show that oil and gas wells routinely leak, allowing for the migration of natural gas and potentially other substances into groundwater and the atmosphere. Leakage from faulty wells is an issue that the industry has identified and for which it has no solution. For instance, Schlumberger, one of the world's largest companies specializing in fracking, published an article in its magazine in 2003 showing that about five percent of wells leak immediately, 50 percent leak after 15 years and 60 percent leak after 30 years. Data from Pennsylvania's Department of Environmental Protection (DEP) also confirm these initial leakage rates, with a six percent structural integrity failure rate observed for shale gas wells drilled in 2010, 7.1 percent observed for wells drilled in 2011, and 8.9 percent observed for wells drilled in 2012. Leaks pose serious risks including potential loss of life or property from explosions and the migration of gas or other chemicals into drinking water supplies. Leaks also allow methane to escape into the atmosphere, where it acts as a powerful greenhouse gas. There is no evidence to suggest that the problem of cement and well casing impairment is abating. Indeed, a 2014 analysis of more than 75,000 compliance reports for more than 41,000 wells in Pennsylvania found that newer wells have higher leakage rates and that unconventional shale gas wells leak more than conventional wells drilled within the same time period. Industry has no solution for rectifying the chronic problem of well casing leakage.

- **Radioactive releases –** High levels of radiation documented in fracking wastewater raise special concerns in terms of impacts to groundwater and surface water. Studies have indicated that the Marcellus Shale is more radioactive than other shale formations. Measurements of radium in fracking wastewater in New York and Pennsylvania have been as high as 3,600 times the United States Environmental Protection Agency's (EPA) limit for drinking water. One recent study found toxic levels of radiation in a Pennsylvania waterway even after fracking wastewater was disposed of through an industrial wastewater treatment plant. In addition, the disposal of radioactive drill cuttings is a concern. Unsafe levels of radon and its decay products in natural gas produced from the Marcellus Shale, known to have particularly high radon content, may also contaminate pipelines and compressor stations, as well as pose risks to end-users when allowed to travel into homes.

- **Occupational health and safety hazards** – Fracking jobs are dangerous jobs. Occupational hazards include head injuries, traffic accidents, blunt trauma, burns, toxic chemical exposures, heat exhaustion, dehydration, and sleep deprivation. As a group, oil and gas industry workers have an on-the-job fatality rate seven times that of other industries. Exposure to silica dust, which is definitively linked to silicosis and lung cancer, was singled out by National Institutes for Occupational Safety and Health as a particular threat to workers in fracking operations where silica sand is used. At the same time, research shows that many gas field workers, despite these serious occupational

hazards, are uninsured or underinsured and lack access to basic medical care.

- **Noise pollution, light pollution and stress –** Drilling and fracking operations and ancillary infrastructure expose workers and nearby residents to continuous noise and light pollution that is sustained for periods lasting many months. Chronic exposure to light at night is linked to adverse health effects, including breast cancer. Sources of fracking-related noise pollution include blasting, drilling, flaring, generators, compressor stations and truck traffic. Exposure to environmental noise pollution is linked to cardiovascular disease, cognitive impairment, and sleep disturbance. Workers and residents whose homes, schools and workplaces are in close proximity to well sites are at risk from these exposures as well as from related stressors.

- **Earthquake and seismic activity** – A growing body of evidence links fracking wastewater injection (disposal) wells to earthquakes of magnitudes as high as 5.7, in addition to "swarms" of minor earthquakes and fault slipping. In some cases, the fracking process itself has been linked to earthquakes and seismic activity, including instances in which gas corporations have acknowledged the connection. In New York, this issue is of particular concern to New York City's aqueduct-dependent drinking water supply and watershed infrastructure, as the New York City Department of Environmental Protection (NYC DEP) has warned repeatedly, but similar concerns apply to all drinking water resources. The question of what to do with wastewater remains a problem with no viable, safe solution.

- **Abandoned and active oil and natural gas wells (as pathways for gas and fluid migration)** – Millions of abandoned and undocumented oil and gas wells exist across the United States, according to the U.S. Department of Energy. All serve as potential pathways for pollution, heightening the risks of groundwater contamination and other problems when horizontal drilling and fracking operations intersect with pre-existing vertical channels leading through drinking water aquifers and to the atmosphere. Industry experts, consultants and government agencies including the U.S. Environmental Protection Agency, the U.S. General Accounting Office (now the Government Accountability Office), Texas Department of Agriculture, New York State Department of Environmental Conservation, Pennsylvania Department of Environmental Protection, Illinois Environmental Protection Agency and the British Columbia Oil and Gas Commission have all warned about problems with abandoned wells due to the potential for pressurized fluids and gases to migrate through inactive and in some cases, active wells.

- **Flood risks –** Massive land clearing and forest fragmentation that necessarily accompany well site preparation increase erosion and risks for catastrophic flooding, as do access roads, pipeline easements and other related infrastructure. In addition, in some cases, operators choose to site well pads on flood-prone areas in order to have easy access to water for fracking, to abide by setback requirements intended to keep well pads away from inhabited buildings, or to avoid productive agricultural areas. In turn, flooding increases the dangers of unconventional gas extraction, resulting in the contamination of soils and water supplies, the overflow or breaching of containment ponds, and the escape

of chemicals and hazardous materials. In at least six of the past ten years, New York State has experienced serious flooding in parts of the state targeted for drilling and fracking. Some of these areas have been hit with "100-year floods" in five or more of the past ten years. Gas companies acknowledge threats posed by flooding, and the New York State Department of Environmental Conservation (DEC) has recommended drilling be prohibited from 100-year flood areas; however, accelerating rates of extreme weather events make existing flood maps obsolete, making this approach insufficiently protective.

- **Threats to agriculture and soil quality –** Drilling and fracking pose risks to the agricultural industry. Studies and case reports from across the country have highlighted instances of deaths, neurological disorders, aborted pregnancies, and stillbirths in cattle and goats associated with livestock coming into contact with wastewater. Potential water and air contamination puts soil quality as well as livestock health at risk. Additionally, farmers have expressed concern that nearby fracking operations can hurt the perception of agricultural quality and nullify value-added organic certification.

- **Threats to the climate system –** A range of studies have shown high levels of methane leaks from gas drilling and fracking operations, undermining the notion that natural gas is a climate solution or a transition fuel. Major studies have concluded that early work by the EPA greatly underestimated the impacts of methane and natural gas drilling on the climate. Drilling, fracking and expanded use of natural gas threaten not only to exacerbate climate change but also to stifle investments in, and expansion of, renewable energy.

- **Inaccurate jobs claims, increased crime rates, and threats to property value and mortgages** – Experiences in various states and accompanying studies have shown that the oil and gas industry's promises for job creation from drilling for natural gas have been greatly exaggerated and that many of the jobs are short-lived and/or have gone to out-of-area workers. With the arrival of drilling and fracking operations, communities have experienced steep increases in rates of crime – including sexual assault, drunk driving, drug abuse, and violent victimization, all of which carry public health consequences. Social costs include strain on municipal services and road damage. Economic analyses have found that drilling and fracking operations threaten property values. Additionally, gas drilling and fracking pose an inherent conflict with mortgages and property insurance due to the hazardous materials used and the associated risks.

- **Inflated estimates of oil and gas reserves and profitability** – Industry estimates of oil and gas reserves and profitability of drilling have proven unreliable, casting serious doubts on the bright economic prospects the industry has painted for the public, media and investors. Increasingly, well production has been short-lived, which has led companies to reduce the value of their assets by billions of dollars.

- **Disclosure of serious risks to investors** – Oil and gas companies are required to disclose risks to their investors in an annual Form 10-K. Those disclosures acknowledge the inherent dangers posed by gas drilling and fracking operations, including leaks, spills, explosions, blowouts, environmental damage, property damage, injury and death.

Adequate protections have not kept pace with these documented dangers and inherent risks.

- **Medical and scientific calls for more study and more transparency** – With increasing urgency, groups of medical professionals and scientists are issuing calls for comprehensive, long-term study of the full range of the potential health and ecosystem effects of drilling and fracking. These appeals underscore the accumulating evidence of harm, point to the major knowledge gaps that remain, and denounce the atmosphere of secrecy and intimidation that continues to impede the progress of scientific inquiry. Health professionals and scientists in the United States and around the world have urged tighter regulation of and in some cases, suspension of unconventional gas and oil extraction activities in order to limit, mitigate or eliminate its serious, adverse public health hazards.

Compilation of Studies & Findings

Air pollution

- June 26, 2014 – Public health professionals at the Southwest Pennsylvania Environmental Health Project reported significant recurrent spikes in the amount of particulate matter in the air inside of residential homes located near drilling and fracking operations. Captured by indoor air monitors, the spikes tend to occur at night when stable atmospheric conditions hold particulate matter low to the ground. Director Raina Ripple emphasized that spikes in airborne particulate matter are likely to cause acute health impacts in community members. She added, "What the long term effects are going to be, we're not certain." At this writing, researchers from Yale University and the University of Washington are working to collect and analyze more samples.[3]

- May 21, 2014 – Raising questions about possible links to worsening air pollution from the Uintah Basin's 11,200 oil and gas wells, health professionals reported that infant deaths in Vernal, Utah, rose to six times the normal rate over the past three years. Physician Brian Moench said, "We know that pregnant women who breathe more air pollution have much higher rates of virtually every adverse pregnancy outcome that exists….And we know that this particular town is the center of an oil and gas boom that's been going on for the past five or six years and has uniquely high particulate matter and

[3] McMahon, J. (2014, June 26). Air Pollution Spikes In Homes Near Fracking Wells. *Forbes*. Retrieved July 4, 2014, from http://www.forbes.com/sites/jeffmcmahon/2014/06/26/air-pollution-spikes-in-homes-near-fracking-wells/

high ozone."[4] With air quality that was formerly pristine, Uintah County, Utah received a grade "F" for ozone in the American Lung Association's 2013 State of the Air Report, with 27.3 more high ozone days than 2007.[5]

- May 8, 2014 – Researchers at the National Oceanic and Atmospheric Administration (NOAA) found high levels of methane leaks as well as benzene and smog-forming volatile organic compounds in the air over oil and gas drilling areas in Colorado. Researchers found methane emissions three times higher than previously estimated and benzene and volatile organic compound levels seven times higher than estimated by government agencies. *The Denver Post* noted that Colorado's Front Range has failed to meet federal ozone air quality standards for years.[6]

- April 26, 2014 – A Texas jury awarded a family $2.8 million because, according to the lawsuit, a fracking company operating on property nearby had "created a 'private nuisance' by producing harmful air pollution and exposing [members of the affected family] to harmful emissions of volatile organic compounds, toxic air pollutants and diesel exhaust." The family's 11-year-old daughter became ill, and family members suffered a range of symptoms, including "nosebleeds, vision problems, nausea, rashes, blood pressure issues."[7] Because drilling did not occur on their property, the family had initially been unaware that their symptoms were caused by activities around them.

- April 16, 2014 – Reviewing the peer-review literature to date of "direct pertinence to the environmental public health and environmental exposure pathways," a U.S. team of researchers concluded: "[a] number of studies suggest that shale gas development contributes to levels of ambient air concentrations known to be associated with increased risk of morbidity and mortality."[8]

  April 11, 2014 – A modeling study commissioned by the state of Texas made striking projections about worsening air quality in the Eagle Ford Shale. Findings included the possibility of a 281 percent increase in emissions of volatile organic compounds (VOCs). Some VOCs cause respiratory and neurological problems; others, like benzene, are also carcinogens. Another finding was that nitrogen oxides—which react with VOCs in

[4] S Schlanger, Z. (2014, May 21). In Utah boom town, a spike in infant deaths raises questions. *Newsweek*. Retrieved June 10, 2014, from http://www.newsweek.com/2014/05/30/utah-boom-town-spike-infant-deaths-raises-questions-251605.html
[5] American Lung Association. (2013). American Lung Association state of the air 2013. Retrieved June 10, 2014, from http://www.stateoftheair.org/2013/states/utah/uintah-49047.html
[6] Finley, B. (2014, May 8). Scientists flying over Colorado oil boom find worse air pollution. *The Denver Post*. Retrieved June 10, 2014, from http://www.denverpost.com/environment/ci_25719742/scientists-flying-over-colorado-oil-boom-find-worse
[7] Morris, J. (2014, April 26). Texas family plagued with ailments gets $3M in 1st-of-its-kind fracking judgment. *CNN*. Retrieved June 10, 2014, from http://www.cnn.com/2014/04/25/justice/texas-family-wins-fracking-lawsuit/
[8] Shonkoff, S. B., Hays, J., & Finkel, M. L. (2014). Environmental public health dimensions of shale and tight gas development [Abstract]. *Environmental Health Perspectives*. doi: 10.1289/ehp.1307866

sunlight to create ground-level ozone, the main component of smog—increased 69 percent during the peak ozone season."[9]

- March 29, 2014 – Scientists warn that current methods of collecting and analyzing emissions data do not accurately assess health risks. Researchers with the Southwest Pennsylvania Environmental Health Project showed that methods do not adequately measure the intensity, frequency or durations of community exposure to the toxic chemicals routinely released from drilling and fracking activities. They found that exposures may be underestimated by an order of magnitude, mixtures of chemicals are not taken into account, and local weather conditions and vulnerable populations are ignored.[10]

- March 27, 2014 – University of Texas research pointed to "potentially false assurances" in response to community health concerns in shale gas development areas. Dramatic shortcomings in air pollution monitoring to date include no accounting for cumulative toxic emissions or children's exposures during critical developmental stages, and the potential interactive effects of mixtures of chemicals. Chemical mixtures of concern include benzene, toluene, ethylbenzene, and xylenes.[1112]

- March 13, 2014 – Volatile organic compounds (VOCs) emitted in Utah's heavily drilled Uintah Basin led to 39 winter days exceeding the EPA's eight-hour National Ambient Air Quality Standards level for ozone pollutants the previous winter. "Levels above this threshold are considered to be harmful to human health, and high levels of ozone are known to cause respiratory distress and be responsible for an estimated 5,000 premature deaths in the U.S. per year," according to researchers at the University of Colorado. Their observations "reveal a strong causal link between oil and gas emissions, accumulation of air toxics, and significant production of ozone in the atmospheric surface layer."[13] Researchers estimated that total annual VOC emissions at the fracking sites are equivalent to those of about 100 million cars.[14]

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[9] Morris, J., Song, L., & Hasemayer, D. (2014, April 11). Report: Air quality to worsen in Eagle Ford shale. *The Texas Tribune*. Retrieved June 10, 2014, from http://www.texastribune.org/2014/04/11/report-air-quality-worsen-eagle-ford-shale/

[10] Brown, D., Weinberger, B., Lewis, C., & Bonaparte, H. (2014). Understanding exposure from natural gas drilling puts current air standards to the test. *Reviews on Environmental Health, 0*(0). doi: 10.1515/reveh-2014-0002

[11] Rawlins, R. (2013). Planning for fracking on the Barnett shale: Urban air pollution, improving health based regulation, and the role of local governments. *Virginia Environmental Law Journal, 31*, 226-306. Retrieved June 10, 2014, from http://www.velj.org/uploads/1/2/7/0/12706894/2._rawlins_-_barnett_shale.pdf

[12] University of Texas at Austin. (2014, March 27). Air pollution and hydraulic fracturing: Better monitoring, planning and tracking of health effects needed in Texas. Retrieved June 10, 2014, from http://www.utexas.edu/news/2014/03/27/hydraulic-fracturing-texas/

[13] Helmig, D., Thompson, C. R., Evans, J., Boylan, P., Hueber, J., & Park, J. (2014). Highly elevated atmospheric levels of volatile organic compounds in the Uintah Basin, Utah [Abstract]. *Environmental Science & Technology, 48*(9), 4707-4715. doi: 10.1021/es405046r

[14] Lockwood, D. (2014, March 25). Harmful air pollutants build up near oil and gas fields. *Chemical & Engineering News*. Retrieved June 10, 2014, from http://cen.acs.org/articles/92/web/2014/03/Harmful-Air-Pollutants-Build-Near.html

- March 3, 2014 – In a report summarizing "the current understanding of local and regional air quality impacts of natural gas extraction, production, and use," a group of researchers from the NOAA, Stanford, Duke, and other institutions described what is known and unknown with regard to air emissions including greenhouse gases, ozone precursors (volatile organic compounds and nitrogen oxides), air toxics, and particulates. Crystalline silica was also discussed, including as a concern for people living near well pads and production staging areas.[15]

- February 18, 2014 – An eight-month investigation by the *Weather Channel*, *Center for Public Integrity* and *InsideClimate News* into fracking in the Eagle Ford Shale in Texas revealed that fracking is "releasing a toxic soup of chemicals into the air." They noted very poor monitoring by the state of Texas and reported on hundreds of air complaints filed relating to air pollution associated with fracking.[16]

- January 28, 2014 – Congenital heart defects and possibly neural tube defects in babies were associated with the density and proximity of natural gas wells within a 10-mile radius of mothers' residences in a study of almost 25,000 births from 1996-2009 in rural Colorado. The researchers note that natural gas development emits several chemicals known to increase risk of birth defects (teratogens).[17]

- January 4, 2014 – As summarized by *Bloomberg View* Editorial Board's Mark Whitehouse, preliminary data from researchers at Princeton University, Columbia University and MIT showed elevated rates of low birthweight among infants born to mothers living near drilling and fracking operations during their pregnancies.[18]

- December 18, 2013 – An interdisciplinary group of researchers in Texas collected air samples in residential areas near shale gas extraction and production, going beyond previous Barnett Shale studies by including emissions from the whole range of production equipment. They found that most areas had "atmospheric methane concentrations considerably higher than reported urban background concentrations," and many toxic chemicals were "strongly associated" with compressor stations.[19]

- December 10, 2013 – Health department testing at fracking sites in West Virginia revealed dangerous levels of benzene in the air. Wheeling-Ohio County Health Department Administrator Howard Gamble stated, "The levels of benzene really pop out.

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[15] Moore, C. W., Zielinska, B., Petron, G., & Jackson, R. B. (2014). Air impacts of increased natural gas acquisition, processing, and use: A critical review. *Environmental Science & Technology*. doi: 10.1021/es4053472

[16] Morris, J., Song, L., & Hasemayer, D. (2014, February 18). Fracking the Eagle Ford Shale. *The Weather Channel*. Retrieved June 10, 2014, from http://stories.weather.com/fracking

[17] McKenzie, L. M., Guo, R., Witter, R. Z., Savitz, D. A., Newman, L. S., & Adgate, J. L. (2014). Birth outcomes and maternal residential proximity to natural gas development in rural Colorado. *Environmental Health Perspectives, 122*, 412-417. doi: 10.1289/ehp.1306722

[18] Whitehouse, M. (2014, January 4). Study shows fracking is bad for babies. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloombergview.com/articles/2014-01-04/study-shows-fracking-is-bad-for-babies

[19] Rich, A., Grover, J. P., & Sattler, M. L. (2014). An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. *Journal of the Air & Waste Management Association, 64*(1), 61-72. doi: 10.1080/10962247.2013.832713

The amounts they were seeing were at levels of concern. The concerns of the public are validated."[20]

- October, 2013 – A preliminary 2013 Cornell University study of the health impacts of oil and gas extraction on infant health in Colorado found that proximity to wells—linked with air pollutants from fracking operations—was associated with reductions in average birthweight and length of pregnancy as well as increased risk for low birthweight and premature birth.[21] A study by the same author, currently under review, analyzed births to Pennsylvania mothers residing close to a shale gas well in Pennsylvania from 2003-2010 also identified increased risk of adverse effects. This includes low birth weight, as well as a 26% increase in APGAR scores under 8 (APGAR—or American Pediatric Gross Assessment Record—is a measure of newborn responsiveness. Scores of less than 8 predict an increase in the need for respiratory support).[22]

- October 11, 2013 – Air sampling before, during, and after drilling and fracking of a new natural gas well pad in rural western Colorado documented the presence of the toxic solvent methylene chloride, along with several polycyclic aromatic hydrocarbons (PAHs) at "concentrations greater than those at which prenatally exposed children in urban studies had lower developmental and IQ scores."[23]

- September 19, 2013 – In Texas, air monitoring data in the Eagle Ford Shale area revealed potentially dangerous exposures of nearby residents to hazardous air pollutants, including cancer-causing benzene and the neurological toxicant, hydrogen sulfide.[24]

- September 13, 2013 – A study by researchers at the University of California at Irvine found dangerous levels of volatile organic compounds in Canada's "Industrial Heartland" where there are more than 40 oil, gas and chemical facilities. The researchers noted high levels of hematopoietic cancers (leukemia and non-Hodgkin's lymphoma) in men who live closer to the facilities.[25]

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[20] Junkins, C. (2013, December 10). Health dept. concerned about benzene emissions near local gas drilling sites. *The Intelligencer, Wheeling News-Register*. Retrieved June 10, 2014, from http://www.theintelligencer.net/page/content.detail/id/593209/Health-Dept--Concerned-About-Benzene-Emissions-Near-Local-Gas-Drilling-Sites.html?nav=510

[21] Hill, E. L. (2013, October). The impact of oil and gas extraction on infant health in Colorado. Retrieved June 10, 2014, from http://www.elainelhill.com/research

[22] Hill, E.L. (2013, December). Shale Gas Development and Infant Health: Evidence from Pennsylvania (under review). Retrieved June 23, 2014 from http://www.elainelhill.com/research.

[23] Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2014). An Exploratory Study of Air Quality Near Natural Gas Operations. *Human and Ecological Risk Assessment: An International Journal, 20*(1), 86-105. doi: 10.1080/10807039.2012.749447

[24] Wilson, S., Sumi, L., & Subra, W. (2013, September 19). Reckless endangerment while fracking the Eagle Ford shale. *Earthworks*. Retrieved June 10, 2014, from http://www.earthworksaction.org/library/detail/reckless_endangerment_in_the_eagle_ford_shale#.UkGi-4Y3uSo.

[25] Blake, D. R. Air quality in the Industrial Heartland of Alberta, Canada and potential impacts on human health. *Atmospheric Environment*, 702-709. Retrieved June 16, 2014, from http://concernedhealthny.org/wp-content/uploads/2013/07/Simpson2013-AE-in-press.pdf

- August 26, 2013 – Medical experts at a rural clinic in heavily drilled Washington County, PA reported case studies of 20 individuals with acute symptoms consistent with exposure to air contaminants known to be emitted from local fracking operations.[26, 27]

- May 2, 2013 – Reports of symptoms commonly linked to exposure to elevated levels of ground-level ozone associated with gas drilling have been documented in shale-heavy states. In Pennsylvania in 2012, a study of more than 100 state residents living near gas facilities found that reported health symptoms closely matched the scientifically established effects of chemicals detected through air and water testing at those nearby sites, and that those negative health effects occurred at significantly higher rates in households closer to the gas facilities than those further away.[28] Indicative of the growing prevalence of such health impacts in the state, a poll showed that two-thirds of Pennsylvanians support a moratorium on fracking because of concern about negative health impacts.[29]

- April 29, 2013 – Using American Lung Association data, researchers with the Environmental Defense Fund determined that air quality in rural areas with fracking was worse than air quality in urban areas.[30]

- March, 2013 – A review of regional air quality damages in parts of Pennsylvania in 2012 from Marcellus Shale development found that air pollution was a significant concern, with regional damages ranging from $7.2 to $32 million dollars in 2011.[31]

- February 27, 2013 – In a letter from Concerned Health Professionals of New York to Governor Andrew Cuomo, a coalition of hundreds of health organizations, scientists, medical experts, elected officials and environmental organizations noted serious health concerns about the prospects of fracking in New York State, making specific note of air pollution.[32] Signatory organizations included the American Academy of Pediatrics of New York, the American Lung Association of New York and Physicians for Social

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[26] Abrams, L. (2013, August 26). Fracking's real health risk may be from air pollution. *Salon*. Retrieved June 10, 2014, from http://www.salon.com/2013/08/26/frackings_real_health_risk_may_be_from_air_pollution/

[27] Dyrszka, L., Nolan, K., & Steingraber, S. (2013, August 27). *Statement on preliminary findings from the Southwest Pennsylvania Environmental Health Project study. Press release*. Concerned Health Professionals of NY. Retrieved June 10, 2014, from http://concernedhealthny.org/statement-on-preliminary-findings-from-the-southwest-pennsylvania-envir...

[28] Steinzor, N., Subra, W., & Sumi, L. (2013). Investigating Links between Shale Gas Development and Health Impacts Through a Community Survey Project in Pennsylvania. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 55-83. doi: 10.2190/NS.23.1.e

[29] Phillips, S. (2013, May 14). Poll shows support for a drilling moratorium in Pennsylvania. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/pennsylvania/2013/05/14/poll-shows-support-for-a-drilling-moratorium-in-pennsylvania/

[30] Grossman, D. (2013, April 29). Clean air report card: CO, WY Counties get F's due to oil and gas pollution. *Environmental Defense Fund*. Retrieved June 10, 2014, from http://blogs.edf.org/energyexchange/2013/04/29/clean-air-report-card-co-wy-counties-get-fs-due-to-oil-and-gas-pollution/#sthash.FXRV6Nxi.dpuf

[31] Litovitz, A., Curtright, A., Abramzon, S., Burger, N., & Samaras, C. (2013). Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania. *Environmental Research Letters, 8*(1). doi: 10.1088/1748-9326/8/1/014017

[32] Concerned Health Professionals of NY. (2013, February 27). Letter to Governor Cuomo. Retrieved June 10, 2014, from http://concernedhealthny.org/letters-to-governor-cuomo/

Responsibility. The New York State Medical Society, representing 30,000 medical professionals, has issued similar statements.[33]

- January 2, 2013 – A NOAA study identified emissions from oil and gas fields in Utah as a significant source of pollutants that contribute to ozone problems.[34] Exposure to elevated levels of ground-level ozone is known to worsen asthma and has been linked to respiratory illnesses and increased risk of stroke and heart attack.[35]

- December 3, 2012 – A study linked a single well pad in Colorado to more than 50 airborne chemicals, 44 of which have known health effects.[36]

- July 18, 2012 – A study by the Houston Advanced Research Center modeled ozone formation from a natural gas processing facility using accepted emissions estimates and showed that regular operations could significantly raise levels of ground-level ozone (smog) in the Barnett Shale in Texas and that gas flaring further contributed to ozone levels.[37]

- March 19, 2012 – A Colorado School of Public Health study found air pollutants near fracking sites linked to neurological and respiratory problems and cancer.[3839] The study, based on three years of monitoring at Colorado sites, found a number of "potentially toxic petroleum hydrocarbons in the air near gas wells including benzene, ethylbenzene, toluene and xylene." Lisa McKenzie, PhD, MPH, lead author of the study and research associate at the Colorado School of Public Health, said, "Our data show that it is important to include air pollution in the national dialogue on natural gas development that has focused largely on water exposures to hydraulic fracturing."[40]

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[33] Campbell, J. (2013, April 17). Fracking roundup: Gas prices up; Medical society wants moratorium. *Politics on the Hudson*. Retrieved June 10, 2014, from http://polhudson.lohudblogs.com/2013/04/17/fracking-roundup-gas-prices-up-medical-society-wants-moratorium/

[34] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12-12. doi: 10.1038/493012a

[35] American Lung Association. (2013). American Lung Association state of the air 2013 - Ozone pollution. Retrieved June 10, 2014, from http://www.stateoftheair.org/2013/health-risks/health-risks-ozone.html

[36] Song, L. (2012, December 3). Hazardous air pollutants detected near fracking sites. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2012-12-03/hazardous-air-pollutants-detected-near-fracking-sites.html

[37] Olaguer, E. P. (2012). The potential near-source ozone impacts of upstream oil and gas industry emissions. *Journal of the Air & Waste Management Association, 62*(8), 966-977. doi: 10.1080/10962247.2012.688923

[38] Kelly, D. (2012, March 19). Study shows air emissions near fracking sites may pose health risk. *University of Colorado Denver*. Retrieved June 10, 2014, from http://www.ucdenver.edu/about/newsroom/newsreleases/Pages/health-impacts-of-fracking-emissions.aspx

[39] McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment, 424*, 79-87. doi: 10.1016/j.scitotenv.2012.02.018

[40] Banerjee, N. (2012, March 20). Study: 'Fracking' may increase air pollution health risks. *Los Angeles Times*. Retrieved June 11, 2014, from http://articles.latimes.com/2012/mar/20/local/la-me-gs-fracking-increases-air-pollution-health-risks-to-residents-20120320

- December 12, 2011 – Cancer specialists, cancer advocacy organizations, and health organizations summarized the cancer risks posed by all stages of the shale gas extraction process in a letter to New York Governor Andrew Cuomo.[41]

- October 5, 2011 – More than 250 medical experts and health organizations reviewed the multiple health risks from fracking in a letter sent to New York Governor Andrew Cuomo.[42]

- April 21, 2011 – *Environment & Energy (E&E)* reported that ozone levels exceeding federal health standards in Utah's Uintah Basin, as well as wintertime ozone problems in other parts of the Intermountain West, stem from oil and gas extraction. Levels reached nearly twice the federal standard, potentially dangerous even for healthy adults to breathe. Keith Guille, spokesman for the Wyoming Department of Environmental Quality, said, "We recognize that definitely the main contributor to the emissions that are out there is the oil and gas industry…."[43]

- March 8, 2011 – The Associated Press reported that gas drilling in some remote areas of Wyoming caused a decline of air quality from pristine mountain air to levels of smog and pollution worse than Los Angeles on its worst days, resulting in residents complaining of watery eyes, shortness of breath and bloody noses.[44]

- November 18, 2010 – A study of air quality in the Haynesville Shale region of east Texas, northern Louisiana, and southwestern Arkansas found that shale oil and gas extraction activities contributed significantly to ground-level ozone (smog) via high emissions of ozone precursors, including volatile organic compounds and nitrogen

[41] Physicians, Scientists & Engineers for Healthy Energy. (2011, December 12). Appeal to Gov. Cuomo to consider cancer risks re: High volume hydraulic fracturing for natural gas [Letter to A. Cuomo].
[42] Physicians, Scientists & Engineers for Healthy Energy. (2011, October 5). Letter to Governor Cuomo [Letter to A. Cuomo].
[43] Streater, S. (2011, April 21). Air pollution: Winter ozone problem continues to mystify regulators, industry. *E&E Publishing, LLC*. Retrieved June 11, 2014, from http://www.eenews.net/stories/1059948108
[44] Gruver, M. (2011, March 8). Wyoming is beset by a big-city problem: Smog. *USA Today*. Retrieved June 11, 2014, from http://usatoday30.usatoday.com/money/industries/energy/2011-03-08-natural-gas-ozone-wyoming_N.htm

oxides.[45] Ozone is a key risk factor for asthma and other respiratory and cardiovascular illnesses.[46] [47] [48] [49]

- September, 2010 – A health assessment by the Colorado School of Public Health for gas development in Garfield County, Colorado determined that air pollution will likely "be high enough to cause short-term and long-term disease, especially for residents living near gas wells. Health effects may include respiratory disease, neurological problems, birth defects and cancer."[50] [51]

- January 27, 2010 – Of 94 drilling sites tested for benzene in air over the Barnett Shale, the Texas Commission on Environmental Quality (TECQ) discovered two well sites emitting what they determined to be "extremely high levels" and another 19 emitting elevated levels.[52]

Water contamination

- June 25, 2014 – A study by Cornell University researchers found that fracking fluid and fracking wastewater mobilized previously deposited chemical contaminants in soil particles in ways that could potentially exacerbate the impacts of fracking fluid spills or leaks. That research team concluded that, by interfering with the ability of soil to bond to and sequester pollutants such as heavy metals, fracking fluids may release from soils an additional repository of contaminants that could migrate into groundwater.[53]

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[45] Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., ... Yarwood, G. (2010). Ozone Impacts of Natural Gas Development in the Haynesville Shale. *Environmental Science & Technology*, *44*(24), 9357-9363. doi: 10.1021/es1021137

[46] U.S. Environmental Protection Agency. (2013). *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*. Retrieved June 11, 2014, from http://www.epa.gov/ncea/isa/ozone.htm

[47] Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., ... Yarwood, G. (2010). Ozone Impacts of Natural Gas Development in the Haynesville Shale. *Environmental Science & Technology*, *44*(24), 9357-9363. doi: 10.1021/es1021137

[48] McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment*, *424*, 79-87. doi: 10.1016/j.scitotenv.2012.02.018

[49] Myers, O., Flowers, H., Kang, H., Bedrick, E., Whorton, B., Cui, X., & Stidley, C. A. (2007). *The association between ambient air quality ozone levels and medical visits for asthma in San Juan County* (U.S.A., New Mexico Department of Health, Environmental Health Epidemiology Bureau Epidemiology and Response Division).

[50] Witter, R., McKenzie, L., Towle, M., Stinson, K., Scott, K., Newman, L., & Adgate, J. (2010). Health impact assessment for Battlement Mesa, Garfield County Colorado. *Colorado School of Public Health*. Retrieved June 10, 2014, from http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf

[51] Battlement Mesa HIA/EHMS. (2013, November 30). Retrieved June 10, 2014, from http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-draft2.aspx

[52] The Associated Press. (2010, January 27). Texas agency finds high benzene levels on Barnett Shale. Retrieved June 10, 2014, from http://www.nola.com/business/index.ssf/2010/01/texas_agency_finds_high_benzen.html

[53] Sang, W., Stoof, C., Zhang, W., Morales, V., Gao, B., Kay, R., et al. Effect of Hydrofracking Fluid on Colloid Transport in the Unsaturated Zone. *Environmental Science & Technology*. Retrieved July 4, 2014, from http://pubs.acs.org/doi/abs/10.1021/es501441e

- June 23, 2014 – Building on earlier findings that water samples collected from sites with confirmed fracking spills in Garfield County, Colorado exhibited moderate to high levels of estrogen and androgen-disrupting activity, a University of Missouri team extended their investigation to other types of hormonal effects. As reported at a joint meeting of the International Society of Endocrinology and the Endocrine Society, their research documented that commonly used fracking chemicals can also block the receptors for thyroid hormone, progesterone, and glucocorticoids (a family of hormones involved in both fertility and immune functioning). Of 24 fracking chemicals tested, all 24 interfered with the activity of one or more important hormone receptors. There is no known safe level of exposure to hormone-disrupting chemicals.[54]

- May 11, 2014 – According to the U.S. Government Accountability Office, the federal government is failing to inspect thousands of oil and gas wells located on public land, including those that pose special risks of water contamination or other environmental damage. An investigation by the Associated Press found that the Bureau of Land Management (BLM) "had failed to conduct inspections on more than 2,100 of the 3,702 wells that it had specified as 'high priority' and drilled from 2009 through 2012. The agency considers a well 'high priority' based on a greater need to protect against possible water contamination and other environmental safety issues."[55]

- March 25, 2014 – An industry-funded study of oil and gas well integrity found that more than six percent of wells in a major shale exploration region in Pennsylvania showed evidence of leaking and conceded that this number is likely an underestimate. Researchers concluded that the percentage of wells with some form of well barrier or integrity failure is highly variable and could be as high as 75 percent. A separate analysis in the same study found 85 examples of cement or casing failures in Pennsylvania wells monitored between 2008 and 2011.[56]

- March 7, 2014 – In a comprehensive evaluation, Duke University scientists and colleagues reviewed the state of knowledge on possible effects of shale gas and hydraulic fracturing on water resources in the United States and concluded, "Analysis of published data (through January 2014) reveals evidence for stray gas contamination, surface water impacts in areas of intensive shale gas development, and the accumulation of radium

[54] The Endocrine Society (2014). Hormone-disrupting activity of fracking chemicals worse than initially found. *Science Daily*, June 23, 2014 Retrieved from: http://www.sciencedaily.com/releases/2014/06/140623103939.htm?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+sciencedaily%2Ftop_news%2Ftop_health+%28ScienceDaily%3A+Top+Health+News%29

[55] Yen, H. (2014, May 11). Fed govt failed to inspect higher risk oil wells. *Associated Press*. Retrieved June 9, 2014, from http://bigstory.ap.org/article/fed-govt-failed-inspect-higher-risk-oil-wells

[56] Davies, R. J., Almond, S., Ward, R. S., Jackson, R. B., Adams, C., Worrall, F., ... Whitehead, M. A. (2014). Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology, 56*, 239-254. doi: 10.1016/j.marpetgeo.2014.03.001

isotopes in some disposal and spill sites."[57]

- February 19, 2014 – A Pennsylvania court found a gas corporation guilty of contaminating a woman's drinking water well in Bradford County. Methane levels after fracking were 1,300 to 2,000 times higher than baseline, according to the court brief. Iron levels and turbidity had also increased. The brief stated, "In short, Jacqueline Place lived for ten months deprived totally of the use of her well, and even after its 'restoration,' has been burdened with a water supply with chronic contamination, requiring constant vigilance and ongoing monitoring."[58]

- January 16, 2014 – Data from the Colorado Oil and Gas Commission showed that fracking-related chemical spills in Colorado exceed an average rate of one spill per day. Of the 495 chemical spills that occurred in that state over a one-year period of time, nearly a quarter impacted ground or surface water. Sixty-three of the spills spread within 1,500 feet of pigs, sheep and cows, and 225 spread within 1,500 feet of buildings.[59]

- January 10, 2014 – Duke University water tests revealed ongoing water contamination in Parker County, Texas, providing evidence that EPA had prematurely ended its prior investigation into the water contamination.[60] A letter sent to the EPA from more than 200 environmental organizations called on the EPA to re-open its investigation.[61]

- January 5, 2014 – An Associated Press investigation into drinking water contamination from fracking in four states—Pennsylvania, Ohio, West Virginia and Texas—found many cases of confirmed water contamination and hundreds more complaints. The Associated Press noted that their analysis "casts doubt on industry view that it rarely happens."[62]

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[57] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es405118y

[58] Gibbons, B. (2014, February 19). Woman wins case against Chesapeake Jaqueline Place of Terry Township to receive compensation for well contamination. *Thedailyreview.com*. Retrieved June 9, 2014, from http://thedailyreview.com/news/woman-wins-case-against-chesapeake-jaqueline-place-of-terry-township-to-receive-compensation-for-well-contamination-1.1636832

[59] Tomasic, J. (2014, January 16). Colorado drilling data: More than a spill a day | The Colorado Independent. *The Colorado Independent*. Retrieved June 9, 2014, from http://www.coloradoindependent.com/145629/colorado-drilling-data-more-than-a-spill-a-day

[60] Drajem, M. (2014, January 9). Duke fracking tests reveal dangers driller's data missed. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2014-01-10/epa-s-reliance-on-driller-data-for-water-irks-homeowners.html

[61] Drajem, M. (2014, January 27). EPA needs fracking review: 'Gasland' maker, environmentalists. *Bloomberg*. Retrieved June 9, 2014, from http://go.bloomberg.com/political-capital/2014-01-27/epa-needs-fracking-review-gasland-producer-environmentalists-say/.

[62] Begos, K. (2014, January 05). 4 states confirm water pollution from drilling. *USA Today*. Retrieved June 9, 2014, from http://www.usatoday.com/story/money/business/2014/01/05/some-states-confirm-water-pollution-from-drilling/4328859/

- December 24, 2013 – A report from the EPA Inspector General concluded that evidence of fracking-related water contamination in Parker County, Texas was sound and faulted the EPA for prematurely ending its investigation there, relying on faulty water testing data from the gas industry in doing so, and failure to intervene when affected residents' drinking water remained unsafe.[63] As reported by *Business Insider*, "The EPA Screwed Up When It Dropped This Fracking Investigation."[64]

- December 16, 2013 – Lead by Susan Nagel of the University of Missouri School of Medicine, researchers documented endocrine-disrupting properties in chemicals commonly used as ingredients of fracking fluid and found similar endocrine-disrupting activity in groundwater and surface water samples collected near drilling and fracking sites in Garfield County, Colorado. Endocrine disruptors are chemicals that interfere with the activity of hormones in the body and, at very low concentrations, can raise the risk of reproductive, metabolic, and neurological disorders, especially when exposures occur in early life. [65] [66] [67]

- December 7, 2013 – Reporting on the second gas leak at a single gas well in one month, the Fort Worth *Star-Telegram* uncovered another inherent risk of fracking for groundwater contamination: Silica sand, which is used as an ingredient in fracking fluid for its ability to prop open the shale fractures, can damage steel pipes as it flows back up the well along with the gas. According to Dan Hill, head of the petroleum engineering department at Texas A&M University, new wells are the most susceptible to sand erosion because "the amount of sand and gas rushing through valves and flow lines is at its greatest when a well first goes into production."[68]

- November 28, 2013 – An Associated Press investigation uncovered nearly 300 oil pipeline spills in North Dakota in the previous ten months, all with no public notification. These were among some 750 "oil field incidents" that had occurred in the state over the same time period, also without public notification. Until the AP inquiry, industry and state officials had kept quiet about one particular "massive spill" that had been

[63] Banjeree, N. (2013, December 24). EPA report on fracking in Texas raises new concerns. *Los Angeles Times*. Retrieved June 9, 2014, from http://www.latimes.com/nation/la-na-epa-fracking-20131225,0,6042944.story#ixzz2oVB9FXVY

[64] Miedema, D. (2013, December 25). The EPA screwed up when it dropped this fracking investigation. *Business Insider*. Retrieved June 9, 2014, from http://www.businessinsider.com/epa-criticized-for-dropping-fracking-investigation-2013-12

[65] Kassotis, C. D., Tillitt, D. E., Davis, J. W., Hormann, A. M., & Nagel, S. C. (2013). Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology*. doi: 10.1210/en.2013-1697

[66] Banerjee, N. (2013, December 16). Hormone-disrupting chemicals found in water at fracking sites. *Los Angeles Times*. Retrieved June 11, 2014, from http://articles.latimes.com/2013/dec/16/science/la-sci-fracking-health-20131217

[67] Endocrine Society. (2013, December 16). Fracking chemicals disrupt hormone function. ScienceDaily. Retrieved June 11, 2014 from www.sciencedaily.com/releases/2013/12/131216140428.htm

[68] Hirst, C., & Fuquay, J. (2013, December 7). Second leak reported at east Fort Worth gas well site. *Star-Telegram*. Retrieved June 9, 2014, from http://www.star-telegram.com/2013/12/07/5399740/second-leak-reported-at-east-fort.html?rh=1

accidentally discovered by a wheat farmer. Even small spills can contaminate water sources permanently and take cropland out of production.[69]

- November 26, 2013 – A U.S. Geological Survey report found serious impacts of fracking on watersheds and water quality throughout the Appalachian Basin, as well as issues with radiation and seismic events. As noted in the report, the knowledge of how extraction affects water resources has not kept pace with the technology.[70] [71] Meanwhile, clean fresh water is becoming an increasingly scant resource. A report from the U.S. State Department found that the United States will face a serious freshwater shortage by 2030, with demand exceeding supply by 40 percent.[72]

- November 22, 2013 – A U.S. Geological Survey study of pollution from oil production in North Dakota, where horizontal drilling and hydraulic fracturing are heavily used, identified two potential plumes of groundwater contamination covering 12 square miles. The cause was traced to a casing failure in a wastewater disposal well. Drilling companies had incorrectly assumed that, once injected underground, the wastewater would remain contained. According to *EnergyWire*, the development of the Bakken oil formation is "leaving behind an imprint on the land as distinct as the ones left by the receding ice sheets of the ice age."[73]

- September 10, 2013 – Pennsylvania Attorney General Kathleen Kane filed criminal charges against Exxon Mobil Corporation's subsidiary, XTO Energy Corporation, for a spill of 50,000 gallons of toxic drilling wastewater in 2010 that contaminated a spring and a tributary of the Susquehanna River. In July, XTO settled civil charges for the incident without admitting liability by agreeing to pay a $100,000 fine and improve its wastewater management.[74]

- September 10, 2013 – Out of concern for risks posed to drinking water in our nation's capital, George Hawkins, general manager of DC Water, Washington, DC's local water provider, called for a prohibition on horizontal drilling and hydraulic fracturing in the

[69] MacPherson, J. (2013, October 28). Nearly 300 pipeline spills in North Dakota have gone unreported to the public since January 2012. *Huffington Post*. Retrieved June 9, 2014, from http://www.huffingtonpost.com/2013/10/28/pipeline-spills-north-dakota_n_4170133.html?ncid=edlinkusaolp00000003

[70] Kappel, W. M., Williams, J. H., & Szabo, Z. (2013). Water resources and shale gas/oil production in the Appalachian Basin - Critical issues and evolving developments. *U.S. Geological Survey*. Retrieved June 9, 2014, from http://pubs.usgs.gov/of/2013/1137/pdf/ofr2013-1137.pdf

[71] Mall, A. (2013, November 26). New USGS analysis: Threats to water, wildlife, and health from oil and gas development in the Appalachian basin [Web log post]. Retrieved June 9, 2014, from http://switchboard.nrdc.org/blogs/amall/new_usgs_analysis.html

[72] A freshwater shortage is expected in the US by 2030. (2013, September 8). *MSN Now*. Retrieved June 11, 2014, from http://now.msn.com/freshwater-shortage-in-us-will-reach-a-worrying-stage-by-2030-1#scpshrtu

[73] Vaidyanathan, G. (2013, November 22). Bakken shale: As oil production sets in, pollution starts to migrate -- scientists. *E&E Publishing, LLC*. Retrieved June 9, 2014, from http://www.eenews.net/stories/1059990892

[74] Maykuth, A. (2013, September 13). Shale criminal charges stun drilling industry. *Philly.com*. Retrieved June 9, 2014, from http://articles.philly.com/2013-09-13/news/42012429_1_xto-energy-inc-criminal-charges-attorney-general

George Washington National Forest until the process can be proven safe.[75] The Potomac River is the source of the District's water supply and has its headwaters in the George Washington National Forest, which sits atop the Marcellus Shale. The general managers of Fairfax Water, provider of drinking water for Fairfax County, Virginia, and the U.S. Army Corps of Engineers have called for a similar prohibition.[76]

- September 3, 2013 – The North Dakota Department of Mineral Resources voiced concern about an increasing number of fracking well blowouts (23 incidents in the past year) that result in spills and public safety threats.[77]

- August 28, 2013 – A joint U.S. Geological Survey and U.S. Fish and Wildlife Service study documented a causal link between a fracking wastewater spill and the widespread death of fish in the Acorn Fork, a creek in Kentucky.[78]

- July 25, 2013 – A University of Texas at Arlington study of drinking water found elevated levels of arsenic and other heavy metals in some samples from private drinking water wells located within 5 km of active natural gas wells in the Barnett Shale.[79] [80]

- July 3, 2013 – *ProPublica* reported that the EPA was wrong to have halted its investigation of water contamination in Wyoming, Texas and Pennsylvania—where high levels of benzene, methane, arsenic, oil, methane, copper, vanadium and other chemicals associated with fracking operations have been documented.[81] Although numerous organizations and health professionals around the country have since called on the agency to resume its investigation, no action has been taken.

- June 6, 2013 – *Bloomberg News* reported,

  > *In cases from Wyoming to Arkansas, Pennsylvania to Texas, drillers have agreed to cash settlements or property buyouts with people who say hydraulic fracturing, also known as fracking, ruined their water according to a review by Bloomberg News of hundreds of regulatory and legal filings. In most cases homeowners must agree to*

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[75] Letter from George Hawkins, General Manager, DC Water, to U.S. Secretary of Agriculture, Thomas Vilsack, (Sept. 10, 2013), http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/.

[76] Wiener, A. (2013, September 20). DC Water Chief urges Agriculture Secretary not to allow fracking near D.C. *Washington City Paper*. Retrieved June 11, 2014, from http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/

[77] Sun Staff. (2013, September 3). More blowouts a concern for N.D. *The Jamestown Sun*. Retrieved June 9, 2014, from http://www.jamestownsun.com/content/more-blowouts-concern-nd

[78] Papoulias, D., & MacKenzie, T. (2013, August 28). Hydraulic fracturing fluids likely harmed threatened Kentucky fish species. *USGS Newsroom*. Retrieved June 9, 2014, from http://www.usgs.gov/newsroom/article.asp?ID=3677

[79] Fontenot, B. E., Hunt, L. R., Hildenbrand, Z. L., Jr., D. D., Oka, H., Walton, J. L., ... Schug, K. A. (2013). An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation. *Environmental Science & Technology, 47*(17), 10032-10040. doi: 10.1021/es4011724

[80] *Id.*

[81] Lustgarten, A. (2013, July 3). EPA's abandoned Wyoming fracking study one retreat of many. *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/epas-abandoned-wyoming-fracking-study-one-retreat-of-many

keep quiet. The strategy keeps data from regulators, policymakers, the news media and health researchers, and makes it difficult to challenge the industry's claim that fracking has never tainted anyone's water.

Bloomberg quoted Aaron Bernstein, associate director of the Center for Health and the Global Environment at the Harvard School of Public Health, saying that non-disclosure agreements "have interfered with the ability of scientists and public health experts to understand what is at stake here."[82] The EPA also long ago noted how non-disclosure agreements challenge scientific progress and keep examples of drilling harm secret from the public. In a 1987 report, the EPA wrote,

Very often damage claims against oil and gas operators are settled out of court, and information on known damage cases has often been sealed through agreements between landowners and oil companies. This is typical practice, for instance, in Texas. In some cases, even the records of well-publicized damage incidents are almost entirely unavailable for review. In addition to concealing the nature and size of any settlement entered into between the parties, impoundment curtails access to scientific and administrative documentation of the incident.[83]

- June 3, 2013 – A study by Duke University researchers linked fracking with elevated levels of methane, ethane, and propane in nearby groundwater.[84] Published in *Proceedings of the National Academy of Sciences*, the study included results from 141 northeastern Pennsylvania water wells. Methane levels were, on average, six times higher in drinking water wells closer to drilling sites when compared with those farther away, while ethane was 23 times higher.[85]

- May 19, 2013 – In Pennsylvania, the *Scranton Times-Tribune* released details of an investigation that revealed at least 161 cases of water contamination from fracking between 2008 and the fall of 2012, according to state Department of Environmental Protection records.[86]

- April 2013 – Researchers analyzing publicly available Colorado data found 77 surface spills impacting groundwater in Weld County alone. Samples of these spills often exceeded drinking water maximum contaminant levels (MCLs) for benzene, toluene,

[82] Efstathiou, J., Jr., & Drajem, M. (2013, June 5). Drillers Silence Fracking Claims With Sealed Settlements. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2013-06-06/drillers-silence-fracking-claims-with-sealed-settlements.html

[83] Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 137-138. Washington, D.C.: U.S. Environmental Protection Agency.

[84] Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., ... Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences*, 110(28), 11250-11255. doi: 10.1073/pnas.1221635110

[85] CBS/AP. (2013, June 25). Methane found in Pa. drinking water near fracked wells. *CBS News*. Retrieved June 9, 2014, from http://www.cbsnews.com/news/methane-found-in-pa-drinking-water-near-fracked-wells/

[86] Legere, L. (2013, May 19). Sunday Times review of DEP drilling records reveals water damage, murky testing methods. *The Times-Tribune*. Retrieved June 9, 2014, from http://thetimes-tribune.com/news/sunday-times-review-of-dep-drilling-records-reveals-water-damage-murky-testing-methods-1.1491547

ethylbenzene and xylene; for benzene, a known carcinogen, 90% of the samples exceeded the legal limit.[87]

- March 4, 2013 – Researchers at the University of Pittsburgh Graduate School of Public Health analyzed samples of gas drilling wastewater discharged to surface water through wastewater treatment plants. Barium, strontium, bromides, chlorides, and benzene all exceeded levels known to cause human health impacts.[88]

- December 9, 2012 – State data in Colorado showed more than 350 instances of groundwater contamination resulting from more than 2,000 spills from oil and gas operations over the past five years. Further, as the *Denver Post* reported, "Contamination of groundwater—along with air emissions, truck traffic and changed landscapes—has spurred public concerns about drilling along Colorado's Front Range."[89]

- May, 2012 – A report by researchers at Natural Resources Defense Council and Carnegie Mellon University found that the options available for dealing with fracking wastewater are inadequate to protect public health and the environment, resulting in increasing quantities of toxic wastewater as an ongoing problem without a good solution.[90]

- January 11, 2012 – The U.S. Geological Survey found that the Marcellus Shale is already highly fractured and that numerous fissures naturally occurring within the formation could potentially provide pathways for contaminants to migrate vertically into water supplies.[91]

- October 17, 2011 – Thomas P. Jacobus, General Manager of the U.S. Army Corps of Engineers' Washington Aqueduct, that provides drinking water to Washington, DC, Arlington County, Virginia, and Falls Church, Virginia, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest because of concern that fracking poses risks to drinking water. The Washington Aqueduct—which provides drinking water to Washington, DC, Arlington County, Virginia, and Falls Church, Virginia—is supplied by the Potomac River, which has its headwaters in the George Washington National Forest that sits atop the Marcellus Shale. Jacobus said, "Enough study on the technique [hydraulic fracturing] has been published to give us great

[87] Gross, S. A., Avens, H. J., Banducci, A. M., Sahmel, J., Panko, J. M., & Tvermoes, B. E. (2013). Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations. *Journal of the Air & Waste Management Association, 63*(4), 424-432. doi: 10.1080/10962247.2012.759166

[88] Ferrar, K. J., Michanowicz, D. R., Christen, C. L., Mulcahy, N., Malone, S. L., & Sharma, R. K. (2013). Assessment of effluent contaminants from three facilities discharging Marcellus shale wastewater to surface waters in Pennsylvania. *Environmental Science & Technology*, *47*(7), 3472-3481. doi: 10.1021/es301411q

[89] Finley, B. (2012, December 9). Drilling spills reaching Colorado groundwater; state mulls test rules. *The Denver Post*. Retrieved June 9, 2014, from http://www.denverpost.com/environment/ci_22154751/drilling-spills-reaching-colorado-groundwater-state-mulls-test#ixzz2EihHU2fg

[90] Hammer, R., & VanBriesen, J. (2012, May). *In fracking's wake: New rules are needed to protect our health and environment from contaminated wastewater* (Rep.). Retrieved June 11, 2014, from National Resource Defence Council website: http://www.nrdc.org/energy/files/fracking-wastewater-fullreport.pdf

[91] U.S. Geological Survey, New York Water Science Center. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement* (Rep.). Retrieved June 11, 2014, from http://www.ewg.org/sites/default/files/report/ReviseddraftSGEIS_USGScomments_Version3_0.pdf

cause for concern about the potential for degradation of the quality of our raw water supply…."[92]

- October 11, 2011 – Charles M. Murray, General Manager of Fairfax Water, the water provider for Fairfax County, Virginia, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest. "Natural gas development activities have the potential to impact the quantity and quality of Fairfax Water's source water," Murray wrote. "Downstream water users and consumers will bear the economic burden if drinking water sources are contaminated or the quality of our source water supply is degraded."[93]

- September 7, 2011 – In its draft Supplemental Generic Environmental Impact Statement (SGEIS), the NYS DEC acknowledged that "there is questionable available capacity"[94] for New York's public sewage treatment plants to accept drilling wastewater, yet the agency said that it would allow those facilities to accept such waste if the plants meet permitting conditions.[95] The NYS DEC proposed underground injection as one alternative to sewage treatment procession of fracking waste. Although it is a common method of disposal for fracking wastewater,[96] the last significant government study of pollution risks from oil and gas wastewater injection wells occurred in 1989 and found multiple cases of costly groundwater contamination.[97] In subsequent years, studies have continued to link underground injection of drilling wastewater to pollution as well as earthquakes.[98]

- September, 2011 – A team led by Theo Colburn of the Endocrine Disruptor Exchange found that 25 percent of chemicals known to be used in fracking fluids are implicated in cancer, 37 percent could disrupt the endocrine system, and 40 to 50 percent could cause

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[92] Jacobus, T. P. (2012, April 25). Draft environmental impact statment for the George Washington National Forest [Letter written October 17, 2011 to K. Landgraf]. Retrieved June 11, 2014, from http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5366331.pdf

[93] Murray, C. M. (n.d.). Draft environmental impact statment for the George Washington National Forest [Letter written October 11, 2013 to K. Landgraf]. Retrieved June 11, 2014, from http://www.svnva.org/wp-content/uploads/fairfax-wash-aquaduct-gwnf-comments.pdf

[94] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-62, Rep.).

[95]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-57 through 6-63, Rep.).

[96]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-64, Rep.).

[97] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved June 10, 2014, from http://www.gao.gov/products/RCED-89-97

[98] Fountain, H. (2012, January 01). Disposal halted at well after new quake in Ohio. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html

nervous, immune and cardiovascular system problems. The research team also found that and more than 75 percent could affect the skin, eyes and respiratory system, resulting in various problems such as skin and eye irritation or flu-like symptoms.[99]

- August 4, 2011 – As reported by *The New York Times*, the EPA had alerted Congress in 1987 about a case of water contamination caused by fracking. Its report documented that a shale gas well hydraulically fractured at a depth of more than 4,200 feet contaminated a water supply only 400 feet from the surface.[100] [101] [102]

- May 17, 2011 – The state of Pennsylvania fined Chesapeake Energy Corp. $900,000 for an incident in which improper cementing and casing in one of the company's gas wells allowed methane to migrate underground and contaminate 16 private drinking water wells in Bradford County.[103]

- May 9, 2011 – A Duke University study documented "systematic evidence for methane contamination of drinking water associated with shale gas extraction." The study showed that methane levels were 17 times higher in water wells near drilling sites than in water wells in areas without active drilling.[104]

- January 2011 – A team of scientists led by a University of Central Arkansas researcher called attention to the threat posed to surface waters by rapidly expanding shale gas development, noting a lack of data collection accompanying the rush to drill. "Gas wells are often close to surface waters that could be impacted by elevated sediment runoff from pipelines and roads, alteration of stream flow as a result of water extraction, and contamination from introduced chemicals or the resulting wastewater."[105]

- April 29, 2010 – In 2010, the Colorado Oil and Gas Conservation Commission fined OXY USA a record $390,000 for an incident of pollution, discovered in 2008, when its drilling wastes leaked through an unlined pit, contaminated two springs with benzene and polluted other nearby water sources. In addition, the regulators separately fined OXY USA $257,400 for a nearby case of pollution, also discovered in 2008, in which a torn

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[99] Colborn, T., Kwiatkowski, C., Schultz, K., & Bachran, M. (2011). Natural Gas Operations from a Public Health Perspective. *Human and Ecological Risk Assessment: An International Journal, 17*(5), 1039-1056. doi: 10.1080/10807039.2011.605662

[100] Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. Retrieved June 11, 2014, from http://www.nytimes.com/2011/08/04/us/04natgas.html

[101] U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 4-22, 4-23. Retrieved June 11, 2014, from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.PDF

[102] Horwitt, D. (2011, August 3). Cracks in the facade. *Environmental Working Group*. Retrieved June 11, 2014, from http://www.ewg.org/research/cracks-façade

[103] Levy, M. (2011, May 18). DEP fines Chesapeake $1 million. *Pressconnects.com*. Retrieved June 9, 2014, from http://www.pressconnects.com/viewart/20110517/NEWS01/105170345/DEP-fines-Chesapeake-1-million

[104] Duke University. (2011). Methane levels 17 times higher in water wells near hydrofracking sites, study finds. *ScienceDaily*. Retrieved June 11, 2014, from http://www.sciencedaily.com/releases/2011/05/110509151234.htm

[105] Entrekin, S., Evans-White, M., Johnson, B., & Hagenbuch, E. (2011). Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment, 9*(9), 503-511. doi: 10.1890/110053

liner in a pit caused drilling waste fluids to leak out and contaminate two springs with benzene.[106]

- April 22, 2011 – Describing one of many blowouts, the Associated Press reported on a shale gas well in Canton, Pennsylvania that spewed thousands of gallons of chemical-laced water on farmland and into a stream for two consecutive days before being brought under control.[107]

- January 31, 2011 – As part of a year-long investigation into hydraulic fracturing and its potential impact on water quality, U.S. Representatives Henry Waxman (D-Calif.), Edward Markey (D-Mass.) and Diana DeGette (D-Colo.) reported that "between 2005 and 2009, oil and gas service companies injected 32.2 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 19 states." Furthermore, revealing apparent widespread violation of the Safe Drinking Water Act, the investigation found that no oil and gas service companies had sought—and no state or federal regulators had issued—permits for the use of diesel fuel in hydraulic fracturing.[108]

- June 5, 2009 – A leaking pipe carrying fracking waste in Washington County, Pennsylvania, polluted a tributary of Cross Creek Lake, killing fish, salamanders, crayfish and aquatic insect life in approximately three-quarters of a mile of the stream.[109]

- April 26, 2009 – Officials in three states linked water contamination and methane leaks to gas drilling Incidents included a case in Ohio where a house exploded after gas seeped into its water well and multiple cases of exploding drinking water wells in Dimock, PA.[110]

- November 13, 2008 – *ProPublica* reported more than 1,000 cases of drilling-related contamination documented by courts and state and local governments in Colorado, New Mexico, Alabama, Ohio and Pennsylvania.[111]

- December 15, 2007 – In Bainbridge, Ohio, a gas well that was improperly cemented and

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[106] Webb, D. (2010, April 29). Record fine, second one against Oxy approved | GJSentinel.com. *Grand Junction Sentinel*. Retrieved June 11, 2014, from http://www.gjsentinel.com/news/articles/record-fine-second-one-against-oxy-approved

[107] The Associated Press. (2011, April 22). Crews stop flow of drilling fluid from Pennsylvania well. *Syracuse.com*. Retrieved June 9, 2014, from http://www.syracuse.com/news/index.ssf/2011/04/crews_stop_flow_of_drilling_fl.html

[108] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, January 31). *Committee on Energy & Commerce* (U.S.A., Congress, Committee on Energy & Commerce). Retrieved June 9, 2014, from http://democrats.energycommerce.house.gov/index.php?q=news/waxman-markey-and-degette-investigation-finds-continued-use-of-diesel-in-hydraulic-fracturing-f

[109] Pittsburgh Post-Gazette. (2009, June 5). Waste from Marcellus shale drilling in Cross Creek Park kills fish. *Pittsburgh Post-Gazette*. Retrieved June 9, 2014, from http://www.post-gazette.com/washington/2009/06/05/Waste-from-Marcellus-shale-drilling-in-Cross-Creek-Park-kills-fish/stories/200906050136

[110] Lustgarten, A. (2009, April 26). Officials in three states pin water woes on gas drilling. *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/officials-in-three-states-pin-water-woes-on-gas-drilling-426

[111] Lustgarten, A. (2008, November 13). Buried secrets: Is natural gas drilling endangering U.S. water supplies? *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113

subsequently fractured by Ohio Valley Energy Systems Corp. allowed natural gas to migrate outside of the well, causing a home to explode. In addition, 23 nearby water wells were contaminated, two of which were located more than 2,300 feet from the drilling site.[112] [113] [114]

Inherent engineering problems that worsen with time

- June 30, 2014 – A study published in *Proceedings of the National Academy of Sciences* by a Cornell University research team projected that over 40 percent of shale gas wells in Northeastern Pennsylvania will leak methane into groundwater or the atmosphere over time. Analyzing more than 75,000 state inspections of more than 41,000 oil and gas wells in Pennsylvania since 2000, the researchers identified high occurrences of casing and cement impairments inside and outside the wells. A comparative analysis showed that newer, unconventional (horizontally fracked) shale gas wells were leaking at six times the rate of conventional (vertical) wells drilled over the same time period. The leak rate for unconventional wells drilled after 2009 was at least 6 percent, and rising with time.[115] The study also discovered that over 8,000 oil and gas wells drilled since 2000 had not received a facility-level inspection. This study helps explain the results of earlier studies that documented elevated levels of methane in drinking water aquifers located near drilling and fracking operations in Pennsylvania and points to compromised structural integrity of well casings and cement as a possible mechanism.

- May 22, 2014 – In a 69-page report, University of Waterloo researchers warned that natural gas seeping from 500,000 wellbores in Canada represents "a threat to environment and public safety" due to groundwater contamination, greenhouse gas emissions and explosion risks wherever methane collects in unvented buildings and spaces. The report found that 10 percent of all active and suspended gas wells in British Columbia now leak methane. Additionally, the report found that some hydraulically fractured shale gas wells in that province have become "super methane emitters" that

[112] Ohio Department of Natural Resources Division of Mineral Resources Management. (2008, September 1). *Report on the investigation of the natural gas invasion of aquifers in Bainbridge Township of Geauga County, Ohio* (Rep.). Retrieved June 9, 2014, from Ohio Department of Natural Resources website: http://www.ohiodnr.com/mineral/bainbridge/tabid/20484/default.aspx

[113] Bair, E. S., Freeman, D. C., & Senko, J. M. (2010, June). *Expert panel technical report, subsurface gas invasion Bainbridge Township, Geauga County, Ohio* (Rep.). Retrieved June 11, 2014, from Ohio Department of Natural Resources website: http://oilandgas.ohiodnr.gov/portals/oilgas/pdf/bainbridge/DMRM%200%20Title%20Page,%20Preface,%20Acknowledgements.pdf

[114] Ohio Dep't of Natural Res., Order Number 2009-17 (Apr. 14, 2009) (see attachments A, B).

[115] Ingraffea, A., Wells, M., Santoro, R., & Shonkoff, S. Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012. *Proceedings of the National Academy of Sciences*. Retrieved July 4, 2014, from http://www.pnas.org/content/early/2014/06/25/1323422111.abstract

spew as much as 2,000 kilograms of methane a year.[116] [117]

- May 1, 2014 – Following a comprehensive review of evidence, the Council of Canadian Academies identified inherent problems with well integrity as one of its top concerns about unconventional drilling and fracking. According to one expert panel, "the greatest threat to groundwater is gas leakage from wells from which even existing best practices cannot assure long-term prevention."[118] Regarding their concerns related to well integrity and cement issues, the panel wrote:

  > *Two issues of particular concern to panel members are water resources, especially groundwater, and GHG emissions. Both related to well integrity…. Natural gas leakage from improperly formed, damaged, or deteriorated cement seals is a long-recognized yet unresolved problem…. Leaky wells due to improperly placed cement seals, damage from repeated fracturing treatments, or cement deterioration over time, have the potential to create pathways for contamination of groundwater resources and to increase GHG emissions.*

  They further explain:

  > *Cement may crack, shrink, or become deformed over time, thereby reducing the tightness of the seal around the well and allowing the fluids and gases … to escape into the annulus between casing and rock and thus to the surface…. The challenge of ensuring a tight cement seal [will] be greater for shale gas wells that are subjected to repeated pulses of high pressure during the hydraulic fracturing process than for conventional gas wells. This pressure stresses the casing and therefore the cement that isolates the well from surrounding formations repeatedly.*

- 2013 – According to state inspections of all 6,000 wells drilled in Pennsylvania's Marcellus Shale before 2013, six to ten percent of them leaked natural gas, with the rate of leakage increasing over time. The rate was six percent in 2010 (97 well failures out of 1,609 wells drilled); 7.1 percent in 2011 (140 well failures out of 1,972 wells drilled); and 8.9 percent in 2012 (120 well failures out of 1,346 wells drilled).[119] These data include wells that were cited for leakage violations, and wells that were noted to be leaking by inspectors but which had not been given violations. The New York State DEC forecasts that 50,000 wells could be drilled over the life of the Marcellus Shale play. If they fail at the same rate as wells in Pennsylvania, 4,000 wells would fail and leak in New York

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[116] Dusseault, M. B., Jackson, R. E., & MacDonal, D. (2014, May 22). *Towards a road map for mitigating the rates and occurrences of long-term wellbore leakage* [Scholarly project]. In *Geofirma*. Retrieved June 10, 2014, from http://www.geofirma.com/Links/Wellbore_Leakage_Study%20compressed.pdf

[117] Nikiforuk, A. (2014, June 5). Canada's 500,000 leaky energy wells: 'Threat to public' *The Tyee*. Retrieved June 10, 2014, from http://www.thetyee.ca/News/2014/06/05/Canada-Leaky-Energy-Wells/

[118] Council of Canadian Academies. (2014, May 1). *Environmental Impacts of Shale Gas Extraction in Canada: the Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction.* Retrieved June 24, 2014, from http://bit.ly/1nNicuf

[119] Ingraffea, A. R. (2013). Some scientific failings within high volume hydraulic fracturing proposed regulations. Retrieved June 10, 2014, from http://www.psehealthyenergy.org/data/NYS_DEC_Proposed_REGS_comments_Ingraffea_Jan_2013.pdf

almost immediately.[120]

- 2009 – A study published by the Society of Petroleum Engineers of more than 315,000 oil, gas and injection wells in Alberta, Canada, found that 4.5 percent of the wells had unintended gas flow to the surface. In one designated area, officials required testing for gas migration outside the well casings in addition to routine testing for gas leaks within the rings of steel casings (annuli). Within this special testing zone, 15.5 percent of wells (3,205 of 20,725) leaked gas, and the incidence of gas leaks was four times percent higher in horizontal or deviated wells than in vertical wells.[121]

- Autumn 2003 – Schlumberger, one of the world's largest companies specializing in hydraulic fracturing and other oilfield services, reported in its in-house publication, *Oilfield Review*, that more than 40 percent of approximately 15,500 wells in the outer continental shelf area in the Gulf of Mexico were leaking gas. These included actively producing wells, in addition to shut-in and temporarily abandoned wells. In many cases, the gas leaked through the spaces (annuli) between layers of steel casing that drilling companies had injected with cement precisely to prevent such gas leaks. Leakage rates increased dramatically with age: about five percent of the wells leaked immediately; 50 percent were leaking after 15 years; and 60 percent were leaking after about 30 years.[122] Gas leaks pose serious risks including loss of life from explosions and migration of gas and associated contaminants into drinking water supplies. Leaks also allow the venting of raw methane into the atmosphere where it acts as a powerful greenhouse gas.

- November 2000 – Maurice Dusseault, a professor at the University of Waterloo in Ontario who specializes in rock mechanics, and two co-authors presented a paper published by the Society of Petroleum Engineers, in which they reported that oil and natural gas wells routinely leak gas through cracks in their cement casings, likely caused by cement shrinkage over time and exacerbated by upward pressure from natural gas. According to their paper, in Alberta, it is common for wells to leak natural gas into aquifers. "Because of the nature of the mechanism, the problem is unlikely to attenuate," they wrote, "and the concentration of the gases in the shallow aquifers will increase with time."[123]

Radioactive releases

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[120]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-1, Rep.).

[121] Watson, T. L., & Bachu, S. (2009). Evaluation of the potential for gas and CO2 leakage along wellbores, society of petroleum engineers. *SPE Drilling & Completion*, 115-126.

[122] Brufatto, C. (2003). From mud to cement - Building gas wells. *Oilfield Review, 15*(3). Retrieved June 10, 2014, from http://www.slb.com/resources/publications/industry_articles/oilfield_review/2003/or2003aut06_building_gas_wells.aspx

[123] Dusseault, M. B., Gray, M. N., & Nawrocki, P. A. (2000). Why oilwells leak: Cement behavior and long-term consequences. *Society of Petroleum Engineers*. Retrieved June 10, 2014, from http://www.hydrorelief.org/frackdata/references/65704543-Casing-Leaks.pdf

- May 8, 2014 – A group of leading medical experts and the American Lung Association of the Northeast detailed research and growing concerns about potential health impacts of radon and radium associated with natural gas production and the Marcellus Shale, in particular. High levels of radiation in the Marcellus Shale could pose health threats if high concentrations of radon and its decay products travel with natural gas, a problem compounded by the short distance Marcellus gas could travel in pipelines to people's homes.[124]

- March 24, 2014 – A team led by toxicology researchers at the University of Iowa identified high levels of radioactivity in fracking wastewater as a significant concern and noted that the testing methods used and recommended by state regulators in the Marcellus Shale region can dramatically underestimate the amount of radioactivity—specifically radium—in fracking wastewater.[125] Results obtained using EPA-recommended protocols can be obscured by a mix of other contaminants present. Regarding the use of EPA protocols with fracking wastewater or other highly saline solutions, Avner Vengosh, a geochemist at Duke University, noted, "People have to know that this EPA method is not updated."[126]

- October 2, 2013 – A peer-reviewed study of the impacts of drilling wastewater treated and discharged into a creek by a wastewater facility in western Pennsylvania documented radium levels approximately 200 times greater in sediment samples near the discharge location than in sediment samples collected upstream of the plant or elsewhere in western Pennsylvania. "The absolute levels that we found are much higher than what you allow in the U.S. for any place to dump radioactive material," one of the authors told *Bloomberg News*. The pollution occurred despite the fact that the treatment plant removed a substantial amount of the radium from the drilling wastewater before discharging it. The researchers wrote that the accumulation of radium in sludge removed from the wastewater "could pose significant exposure risks if not properly managed."[127] [128]

- February 2013 – In an analysis of fracking sludge samples from Pennsylvania, researchers "… confirmed the presence of alpha, beta, and gamma radiation in the soil and water in reserve pits located on agricultural land." Total beta radiation exceeded

[124] Campbell, J. (2014, May 8). Fracking critics keep pushing for state-backed health study. *Politics on the Hudson*. Retrieved June 9, 2014, from http://polhudson.lohudblogs.com/2014/05/08/fracking-critics-keep-pushing-state-backed-health-study/

[125] Nelson, A. W., May, D., Knight, A. W., Eitrheim, E. S., Mehrhoff, M., Shannon, R., ... Schultz, M. K. (2014). Matrix complications in the determination of radium levels in hydraulic fracturing flowback water from Marcellus shale. *Environmental Science & Technology, 1*(3), 204-208. doi: 10.1021/ez5000379

[126] Kelly, S. (2014, March 24). Research shows some test methods miss 99 percent of radium in fracking waste. *Desmogblog.com*. Retrieved June 9, 2014, from http://www.desmogblog.com/2014/03/23/some-testing-methods-can-miss-99-percent-radium-fracking-waste-new-research-reports

[127] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania. *Environmental Science & Technology, 47*(20), 11849-11857. doi: 10.1021/es402165b

[128] Efstathiou, J., Jr. (2013, October 2). Radiation in Pennsylvania creek seen as legacy of fracking. *Bloomberg*. Retrieved June 11, 2014, from http://www.bloomberg.com/news/2013-10-02/radiation-in-pennsylvania-creek-seen-as-legacy-of-frackin.html

regulatory guideline values by more than 800 percent, and elevated levels of some of the radioactive constituents remained in a vacated pit that had been drained and leveled. It is imperative, the research team concluded, "that we obtain better knowledge of the quantity of radioactive material and the specific radioisotopes being brought to the earth's surface from these mining processes."[129]

- January 11, 2012 – In its review of the New York State DEC's SGEIS on high-volume fracturing, the EPA expressed concerns about the diffusion of responsibility for the ultimate disposal of radioactive wastes generated by treatment or pretreatment of drilling wastewater. The EPA also raised concerns about the lack of analysis of radon and other radiation exposure. "Who is responsible for addressing the potential health and safety issues and associated monitoring related to external radiation and the inhalation of radon and its decay products?" the EPA asked. "Such potential concerns need to be addressed."[130]

- 2012 – Responding to concern about radon in natural gas produced from the Marcellus Shale, the U.S. Geological Survey analyzed ten samples of gas collected near the wellheads of three Pennsylvania gas wells. The agency found radon levels ranging from 1 to 79 picocuries per liter, with an average of 36 and a median of 32. (The highest radon activity reported here would decay to 19.8 pCi/L in approximately a week; by comparison, the EPA's threshold for indoor air remediation is 4 pCi/L.) Asserting they knew of no previous published measurements of radon in natural gas from the Appalachian Basin, which contains the Marcellus Shale, agency scientists concluded that the number of samples "is too small to… yield statistically valid results" and urged "collection and interpretation of additional data."[131]

- September 7, 2011 – The U.S. Geological Survey reported that radium levels in wastewater from oil and gas wells in New York and Pennsylvania, including those in the Marcellus Shale, "have a distinctly higher median… than reported for other formations in the Appalachian Basin, and range to higher values than reported in other basins." The median level of radium found in Marcellus Shale wastewater in New York, 5,490 picocuries per liter, is almost 1,100 times the maximum contaminant level for drinking water, which is five picocuries per liter. In other words, if a million gallons of Marcellus Shale wastewater contaminated with the median level of radium found in New York were to spill into a waterway, 1.1 billion gallons of water would be required to dilute the

[129] Rich, A. L., & Crosby, E. C. (2013). Analysis of Reserve Pit Sludge from Unconventional Natural Gas Hydraulic Fracturing and Drilling Operations for the Presence of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM). *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 117-135. doi: 10.2190/NS.23.1.h

[130] Environmental Protection Agency. (2012, January 11). *EPA comments on revised draft NYSDEC revised dSGEIS for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* [Press release]. Retrieved June 10, 2014, from http://www.epa.gov/region2/newsevents/pdf/EPA%20R2%20Comments%20Revised%20dSGEIS%20Enclosure.pdf

[131] Rowan, E. L., & Kraemer, T. F. (2012). *Radon - 222 content of natural gas samples from upper and middle Devonian sandstone and shale reservoirs in Pennsylvania: Preliminary data* (Rep.). Retrieved June 10, 2014, from United States Geological Survey website: http://pubs.usgs.gov/of/2012/1159/ofr2012-1159.pdf

radium to the maximum legal level.[132] (The EPA's health-based goal for radium in drinking water is zero.) Over time, radium naturally decays into radioactive radon gas. Thus, higher radium levels also suggest that higher levels of radon may also be present in natural gas produced from the Marcellus Shale.

- February 27, 2011 – *The New York Times* reported on the threat to drinking water from Pennsylvania drilling waste due to the presence of chemical contaminants, including high levels of radioactivity. The investigation found that sewage treatment plants were neither testing for nor capable of removing that radioactivity, which was subsequently discharged into waterways that supply drinking water. Drillers sent some of this waste to New York State. The article states:

  > *In December 2009, these very risks led E.P.A. scientists to advise in a letter to New York that sewage treatment plants not accept drilling waste with radium levels 12 or more times as high as the drinking-water standard. The Times found wastewater containing radium levels that were hundreds of times this standard. The scientists also said that the plants should never discharge radioactive contaminants at levels higher than the drinking-water standard.*[133]

- 2008-2009 –The New York State DEC found that wastewater from 11 of 13 vertical wells drilled in New York's Marcellus Shale in 2008 and 2009 contained radium levels ranging from 400 times to nearly 3,400 times EPA's safe level for radium in drinking water. These figures later informed the 2011 study of radium in drilling wastewater conducted by the U.S. Geological Survey.[134]

Occupational health and safety hazards

- May 19, 2014 – Underscoring the dangerous nature of chemicals used in fracking operations, the National Institute for Occupational Safety and Health reported that at least four gasfield workers have died since 2010 from acute chemical exposures during flowback operations. They note that research is underway and that significantly more is needed. The National Institute for Occupational Safety and Health reported that flowback operations can "result in elevated concentrations of volatile hydrocarbons in the work environment that could be acute exposure hazards." The agency further noted that such

[132] Rowan, E. L., Engle, M. A., Kirby, C. S., & Kraemer, T. F. (2011, September 7). *Radium content of oil- and gas-field produced waters in the northern Appalachian basin (USA): Summary and discussion of data* (Rep.). Retrieved June 10, 2014, from United States Geological Survey website: http://pubs.usgs.gov/sir/2011/5135/ http://water.epa.gov/drink/contaminants/basicinformation/radionuclides.cfm.
[133] Urbina, I. (2011, February 26). Regulation lax as gas wells' tainted water hits rivers. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all&_r=0
[134] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (5-133, 5-141, 7-60, Appendix 12, Appendix 13, Rep.).

volatile hydrocarbons "can affect the eyes, breathing, and the nervous system and at high concentrations may also affect the heart causing abnormal rhythms."[135] [136]

- May 16, 2013 – A National Institute for Occupational Safety and Health study revealed that worker exposure to crystalline silica—or "frac sand" —exceeded "relevant occupational health criteria" at all eleven tested sites, and the magnitude of some exposures exceeded National Institute for Occupational Safety and Health limits by a factor of 10 or more. "[P]ersonal respiratory protection alone is not sufficient to adequately protect against workplace exposures." Inhalation of crystalline silica can cause incurable silicosis, lung cancer, chronic obstructive pulmonary disease, kidney disease and autoimmune diseases.[137] Although community exposures distant from mines are possible, there are no federal or state standards for silica in ambient air. A first-ever study on public health risks from "frac sand" is now in progress.[138]

- May 8, 2014 – A report by the AFL-CIO found that the fracking boom has made North Dakota the most dangerous state for U.S. workers—with a fatality rate five times higher than the national average—and that North Dakota's fatality rate has doubled since 2007. The AFL-CIO called North Dakota "an exceptionally dangerous and deadly place to work." U.S. Secretary of Labor Thomas E. Perez called the rising rate of workplace deaths suffered in the oil and gas sector "unacceptable."[139]

- April 24, 2014 – A University of Texas San Antonio report commissioned by the Methodist Healthcare Ministries found that many oil and gas field workers in the Eagle Ford Shale are uninsured or underinsured and that "the most noticeable health impacts so far are work-related illnesses and injuries: heat exhaustion, dehydration, sleep deprivation, exposure to oil and gas spills and accidents." The study also noted that oil and gas production has put strain on healthcare facilities.[140]

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[135] Snawder, J., Esswein, E., King, B., Breitenstein, M., Alexander-Scott, M., Retzer, K., ... Hill, R. (2014, May 19). Reports of worker fatalities during flowback operations [Web log post]. *NIOSH Science Blog.* Retrieved June 9, 2014, from http://blogs.cdc.gov/niosh-science-blog/2014/05/19/flowback/

[136] Iafolla, R. (2014, May 20). Four fatalities linked to used fracking fluid exposure during 'flowback,' NIOSH reports. *Bloomberg BNA*. Retrieved June 9, 2014, from http://www.bna.com/four-fatalities-linked-n17179890610/

[137] Esswein, E. J., Breitenstein, M., Snawder, J., Kiefer, M., & Sieber, W. K. (2013). Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing. *Journal of Occupational and Environmental Hygiene, 10*(7), 347-356. doi: 10.1080/15459624.2013.788352

[138] University of Iowa Environmental Health Sciences Research Center. (2012). Exposure assessment and outreach to engage the public on health risks from frac sand mining. Retrieved June 10, 2014, from http://cph.uiowa.edu/ehsrc/fracsand.html

[139] Picchi, A. (2014, May 8). The most dangerous U.S. state for workers. *CBS News*. Retrieved June 10, 2014, from http://www.cbsnews.com/news/the-most-dangerous-us-state-for-workers/

[140] Ghahremani, Y. (2014, April 24). Fractured Healthcare: Pumping Resources Back into the Eagle For Shale Communities/Executive Summary: Methodist Healthcare Ministries and Center for Community and Business Research at the University of Texas San Antonio. Retrieved June 20, 2014, from http://www.joomag.com/en/newsstand/fractured-healthcare-pumping-resources-back-into-the-eagle-ford-shale-communities-apr-2014/0368470001398347080

- April 10, 2014 –West Virginia University researcher Michael McCawley reported that some of the nation's highest rates of silicosis are in heavily drilled areas within the Northern Panhandle of West Virginia and southwestern Pennsylvania. A disease that hardens the lungs through inflammation and development of scar tissue, silicosis is entirely attributable to exposure to silica dust, a known occupational hazard at drilling and fracking operations. Two years earlier, the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health issued a joint "Hazard Alert" to warn fracking workers of the health hazards of exposure to silica dust, including silicosis.[141]

- February 25, 2014 – A year-long investigation by the *Houston Chronicle* found that fracking jobs are deadly, with high fatality rates and high rates of serious injury. Within just one year in Texas, 65 oil and gas workers died, 79 lost limbs, 82 were crushed, 92 suffered burns and 675 broke bones. From 2007 to 2012, at least 664 US workers were killed in oil and gas fields.[142][143]

- December 27, 2013 –National Public Radio (NPR) reported spiking rates of fatalities related to oil and gas drilling operations, which had increased more than 100 percent since 2009. NPR noted that in the previous year, 138 workers were killed on the job, making the fatality rate among oil and gas workers nearly eight times higher than the all-average rate of 3.2 deaths for every 100,000 workers across all industries.[144]

- October 30, 2012 – In a policy statement, the American Public Health Association (APHA) asserted that, high-volume horizontal hydraulic fracturing (HVHF) "poses potential risks to public health and the environment, including groundwater and surface water contamination, climate change, air pollution, and worker health." The statement also noted that the public health perspective has been inadequately represented in policy processes related to HVHF.[145] The policy statement added:

  > *[H]ydraulic fracturing workers are potentially exposed to inhalation health hazards from dust containing silica. There may also be impacts on workers and communities affected by the vastly increased production and transport of sand for HVHF.*

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[141] Hicks, I. (2014, April 10). Gas workers risk silica exposure. *The Intelligencer, Wheeling News-Register*. Retrieved June 10, 2014, from http://www.news-register.net/page/content.detail/id/598589/Gas-Workers-at-Risk-Of-Silica-Ex---.html

[142] Olsen, L. (2014, February 22). Houston Chronicle exclusive: Drilling boom, deadly legacy. Retrieved June 10, 2014, from http://www.houstonchronicle.com/news/special-reports/article/Houston-Chronicle-exclusive-Drilling-boom-5259311.php#/0

[143] Hsieh, S. (2014, February 25). Why are so many workers dying in oil fields? Retrieved June 10, 2014, from http://www.thenation.com/blog/178523/why-are-so-many-workers-dying-oil-fields

[144] Schneider, A., & Geewax, M. (2013, December 27). On-the-job deaths spiking as oil drilling quickly expands. Retrieved June 10, 2014, from http://www.npr.org/2013/12/27/250807226/on-the-job-deaths-spiking-as-oil-drilling-quickly-expands

[145] American Public Health Association. (2012, October 30). The environmental and occupational health impacts of high-volume hydraulic fracturing of unconventional gas reserves. Retrieved June 10, 2014, from http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1439

Inhalation of fine dusts of respirable crystalline silica can cause silicosis. Crystalline silica has also been determined to be an occupational lung carcinogen.

- 2005 – A researcher at Stanford University examined hazards associated with oil and gas extraction from exposure to radiation and determined that inhalation of high-levels of radon gas is a serious concern to workers and those living nearby. "…[G]aseous radon (222Rn) is concentrated in ethane and propane fractions due to the fact that the boiling point of radon lies between those of propane and ethane. Elevated Rn activity concentration values have been measured at several processing plant sites…. It is well known that the radiological impact of the oil and gas-extracting and processing industry is not negligible."[146]

Noise pollution, light pollution and stress

- June 20, 2014 – In its discussion of "Oil and Gas Drilling/Development Impacts," the U.S. Office of Indian Energy and Economic Development detailed noise pollution from bulldozers, drill rigs, diesel engines, vehicular traffic, blasting, and flaring of gas. "If noise-producing activities occur near a residential area, noise levels from blasting, drilling, and other activities could exceed the EPA guidelines. The movement of heavy vehicles and drilling could result in frequent-to-continuous noise…. Drilling noise would occur continuously for 24 hours per day for one to two months or more depending on the depth of the formation."[147] Exposure to chronic noise can be deadly. The World Health Organization has documented the connection between environmental noise and health effects, including cardiovascular disease, cognitive impairment, sleep disturbance, and tinnitus. At least one million "healthy life years" are lost every year from traffic-related noise in the western part of Europe.[148]

- February 24, 2014 – In a review of the health effects from unconventional gas extraction published in the journal *Environmental Science & Technology*, leading researchers noted, "Noise exposure is a significant hazard due to the presence of multiple sources, including heavy equipment, compressors, and diesel powered generators. Loud continuous noise has health effects in working populations. It is likely that exposure to noise is substantial for many workers, and this is potentially important for health because drilling and servicing operations are exempt from some sections of the Occupational Safety and Health Administration noise standard." They noted that research should investigate stressors such as noise and light in the context of drilling and fracking operations in order to understand the overall effect of chemical and physical stressors together.[149]

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[146] Steinhäusler, F. (2005). Radiological Impact on Man and the Environment from the Oil and Gas Industry: Risk Assessment for the Critical Group. *Nato Science Series: IV: Earth and Environmental Sciences.* DOI: 10.1007/1-4020-2378-2_19. http://rd.springer.com/chapter/10.1007/1-4020-2378-2_19

[147] Oil and Gas Drilling/Development Impacts. (n.d.). *Oil and Gas Drilling/Development Impacts*. Retrieved June 20, 2014, from http://teeic.indianaffairs.gov/er/oilgas/impact/drilldev/index.htm

[148] Rodier, G. (2011, June 1). Burden of disease from environmental noise - Quantification of healthy life years lost in Europe. *WHO*. Retrieved June 20, 2014, from http://www.who.int/quantifying_ehimpacts/publications/e94888/en/

[149] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es404621d

May 30, 2014 – *The Denver Post* reported that in order to help meet Colorado's noise limits for fracking operations in suburban neighborhoods (and partially block the glare of floodlights), Encana Oil and Gas erected 4-inch-thick polyvinyl walls up to 32 feet high and 800 feet long. Residents said that the plastic walls do not completely solve the problem.[150]

- October 25, 2013 – An analysis of well location and census data by the *Wall Street Journal* revealed that at least 15.3 million Americans now live within a mile of a well that has been drilled since 2000. According to this investigation, the fracking boom has ushered in "unprecedented industrialization" of communities across wide swaths of the nation and, with it, "24/7" industrial noise, stadium lighting, earth-moving equipment, and truck traffic.[151]

- April 16, 2013 – In a presentation on oil field light pollution for a conference on "Sustainable Environment and Energy: Searching for Synergies," Roland Dechesne of the Royal Astronomical Society of Canada described problems of "light trespass," glare, and poorly-aimed fixtures in oil fields in Alberta. He described resulting "mass waterfowl mortality" linked to artificial illumination and other biochemical impacts of light pollution on wildlife, as well as the possibility of these effects on humans, including circadian disruption, melatonin suppression and possible resulting hormonally-linked diseases.[152] Known to have ecological impacts, outdoor light pollution from drilling and fracking operations may also be linked to artificial light-associated health effects documented in humans, including breast cancer.[153]

- April, 2013 – Led by the University of Pittsburgh Graduate School of Public Health, a study of community members living in proximity to Marcellus Shale drilling in Pennsylvania found adverse impacts to mental health, with stress the most frequently-reported symptom. At least half of all respondents in each set of interviews reported these specific stressors, including: being taken advantage of; health concerns; concerns/complaints ignored; corruption; denied information or provided with false information. Many also reported the desire to move or leave community, estrangement from community, and financial damages. Researchers noted that stress can result in direct health impacts.[154] Notably, mounting evidence indicates that chronic stress magnifies

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[150] Finley, B. (2014, May 29). Oil and gas industry building giant walls to try to ease impact. *The Denver Post*. Retrieved June 20, 2014, from http://www.denverpost.com/ci_25859469/oil-and-gas-industry-building-giant-walls-try

[151] Gold, R. and McGinty T. (2014, Oct. 25). Energy boom puts wells in America's backyards. *The Wall Street Journal.* Retrieved June 21, 2014, from http://online.wsj.com/news/articles/SB10001424052702303672404579149432365326304.

[152] Dechesne, R. (2013). Limiting Oil Field Light Pollution for Safety and the Environment. Sustainable Environment and Energy CPANS 2013 Conference. Retrieved June 20, 2014, from http://www.cpans.org/assets/Uploads/Presentations/NewFolder/Session-46Roland-Dechesne.pdf

[153] Chepesiuk, R. (2009). Missing the Dark: Health Effects of Light Pollution. *Environ Health Perspect*. 117(1): A20–A27.

[154] Ferrar, K.J., Kriesky, J., Christen, C.L., Marshall, L.P., Malone, S.L., Sharma, R.K., Michanowicz. D.R., Goldstein, B.D. (2013). Assessment and longitudinal analysis of health impacts and stressors perceived to result

individuals' susceptibility to effects of pollution; for children, this interactive effect can begin during prenatal life.[155]

- September 7, 2011 – A study by researchers at Boise State University and Colorado State University at Fort Collins modeled the potential impacts of compressor station noise from oil and gas operations on Mesa Verde National Park in Colorado. The study found the sound of 64 compressors outside Mesa Verde elevated the sound level within the park by 34.8 decibels on average, and by 56.8 decibels on the side of the park located closest to the compressors. According to the EPA, 55 decibels is the highest "safe noise level" to avoid damage to the human ear.[156]

Earthquakes and seismic activity

- May 2, 2014 – The U.S. Geological Survey and Oklahoma Geological Survey jointly issued an official earthquake warning for Oklahoma, pointing out that the number of earthquakes in the state has risen 50 percent since just October—when the two agencies had issued a prior warning. The advisory stated that this dramatic increase in the frequency of small earthquakes "significantly increases the chance for a damaging quake in central Oklahoma." Injection wells used for the disposal of liquid fracking waste have been implicated as the presumptive cause of the earthquake swarm. According to the Oklahoma Geological Survey, about 80 percent of the state of Oklahoma is closer than ten miles from an injection well.[157] Since the joint earthquake advisory was released in May, the number of earthquakes in Oklahoma has continued to rise. During the first four months of 2014, Oklahoma had experienced 109 earthquakes of magnitude 3 or higher on the Richter scale. By mid-June, the number of earthquakes had topped 200, exceeding the frequency of earthquakes in California.[158]

- May 2, 2014 – At the annual meeting of the Seismological Society of America, leading geologists warned that the risks and impacts of earthquakes from fracking and injection wells are even more significant than previously thought, pointing out that such earthquakes could occur tens of miles away from wells themselves, including quakes greater than 5.0 magnitude on the Richter scale. Justin Rubinstein, a research geophysicist at the U.S. Geological Survey said, "This demonstrates there is a significant

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from unconventional shale gas development in the Marcellus Shale region. *Int J Occup Environ Health*. Apr-Jun;19(2):104-112. doi: 10.1179/2049396713Y.0000000024.

[155] Cooney, C.M. (2011). Stress–Pollution Interactions: An Emerging Issue in Children's Health Research. *Environ Health Perspect* 119:a430-a435. http://dx.doi.org/10.1289/ehp.119-a430

[156] Barber, J.R., C.L. Burdett, S.E. Reed, K.A. Warner, C. Formichella, K.R. Crooks, D.M. Theobald, and K.M. Fristrup (2011). Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. *Landscape Ecology* 26(9),1281-1295.

[157] Geological Survey Joint Statement. (2014, May 2). Record Number of Oklahoma Tremors Raises Possibility of Damaging Earthquakes. United States Geological Survey. Retrieved June 23, 2014, from http://earthquake.usgs.gov/regional/ceus/products/newsrelease_05022014.php

[158] Branson-Potts, H. (2014, June 17). Oklahoma coming to terms with unprecedented surge in earthquakes. *Los Angeles Times*. Retrieved June 23, 2014, from http://www.latimes.com/nation/la-na-oklahoma-earthquakes-20140618-story.html#page=1

hazard. We need to address ongoing seismicity."[159] Seismologist Gail Atkinson reported, "We don't know how to evaluate the likelihood that a [fracking or wastewater] operation will be a seismic source in advance."[160]

- April 11, 2014 – State geologists reported a link between fracking and a spate of earthquakes in Ohio, prompting the Ohio Department of Natural Resources to place a moratorium on drilling in certain areas and to require greater seismic monitoring.[161]

- April 3, 2014 – Researchers in Mexico linked earthquakes to fracking in the Eagle Ford Shale. They also noted a statistical correlation between seismic activity and fracking, particularly in Nuevo Leon, which registered at least 31 quakes between 3.1 and 4.3 on the Richter scale.[162]

- March 7, 2014 – U.S. Geological Survey researchers published a study confirming that Oklahoma's damaging 5.7 magnitude earthquake in 2011 was caused by fracking wastewater injection.[163] The author of the study, seismologist Elizabeth Cochran with the U.S. Geological Survey, noted, "Even if wastewater injection only directly affects a low-hazard fault, those smaller events could trigger an event on a larger fault nearby."[164]

- January 30, 2014 – A U.S. Geological Survey research team linked the rise in earthquakes in Colorado to fracking wastewater injection wells and announced that a study will be published in six to nine months.[165]

- December 12, 2013 – *The New York Times* detailed the growing link between fracking wastewater injection wells and earthquakes, as well as between fracking itself and earthquakes, with a focus on Oklahoma and a recent magnitude 4.5 earthquake there. As *The New York Times* noted, "Oklahoma has never been known as earthquake country, with a yearly average of about 50 tremors, almost all of them minor. But in the past three years, the state has had thousands of quakes. This year has been the most active, with

[159] Walsh, B. (2014, May 1). The seismic link between fracking and earthquakes. *Time*. Retrieved June 9, 2014, from http://time.com/84225/fracking-and-earthquake-link/
[160] Kiger, P. J. (2014, May 02). Scientists warn of quake risk from fracking operations. *National Geographic*. Retrieved June 9, 2014, from http://news.nationalgeographic.com/news/energy/2014/05/140502-scientists-warn-of-quake-risk-from-fracking-operations/
[161] Dave, P. (2014, April 12). Ohio finds link between fracking and sudden burst of earthquakes. *Los Angeles Times*. Retrieved June 9, 2014, from http://www.latimes.com/nation/nationnow/la-na-nn-ohio-finds-link-fracking-earthquakes-20140411-story.html#axzz2yrnpHW1h
[162] Godoy, E. (2014, April 3). Fracking, seismic activity grow hand in hand in Mexico. *Inter Press Service*. Retrieved June 9, 2014, from http://www.ipsnews.net/2014/04/fracking-seismic-activity-grow-hand-hand-mexico/
[163] Sumy, D. F., Cochran, E. S., Keranen, K. M., Wei, M., & Abers, G. A. (2013). Observations of static Coulomb stress triggering of the November 2011 M5.7 Oklahoma earthquake sequence [Abstract]. *Journal of Geophysical Research: Solid Earth, 119*(3), 1904-1923. doi: 10.1002/2013JB010612
[164] Oskin, B. (2014, March 07). Wastewater injection triggered Oklahoma's earthquake cascade. *Live Science*. Retrieved June 9, 2014, from http://www.livescience.com/43953-wastewater-injection-earthquake-triggering.html
[165] McClurg, L. (2014, January 30). Earthquakes in southern Colorado linked to oil and gas production. *Colorado Public Radio*. Retrieved June 9, 2014, from http://www.cpr.org/news/story/earthquakes-southern-colorado-linked-oil-and-gas-production#sthash.UVvw0JWe.UQwWtYJS.dpuf

more than 2,600 so far, including 87 last week…. State officials say they are concerned, and residents accustomed to tornadoes and hail are now talking about buying earthquake insurance."[166]

- November 19, 2013 – *Reuters* reported that a series of Oklahoma earthquakes in September of 2013 damaged several homes, and that more scientists in a number of states are concerned about earthquakes related to oil and gas development. Seismologist Austin Holland with the University of Oklahoma said, "This is a dramatic new rate of seismicity."[167]

- July 19, 2013 – A study from the Lamont-Doherty Earth Observatory linked 109 earthquakes in Youngstown, Ohio to fracking wastewater disposal.[168][169]

- July 11, 2013 – A study in *Science* by Columbia University's Lamont-Doherty Earth Observatory showed that deep-well injection of fracking waste can stress geological faults in ways that make them vulnerable to slipping. The research shows that distant natural earthquakes triggered swarms of smaller earthquakes on critically stressed faults. The researchers wrote, "The fluids [in wastewater injection wells] are driving the faults to their tipping point…. Areas with suspected anthropogenic earthquakes are more susceptible to earthquake-triggering from natural transient stresses generated by the seismic waves of large remote earthquakes."[170]

- April 2013 – A group of British researchers stated that hydraulic fracturing itself was the likely cause of at least three earthquakes powerful enough to be felt by human beings at the surface. The researchers proposed that increases in the fluid pressure in fault zones were the causal mechanism for these three known instances of "felt seismicity" in the United States, Canada and the United Kingdom. The largest of these earthquakes was a magnitude 3.8 in the Horn River Basin, Canada.[171]

- March 27, 2013 – Scientists from the University of Oklahoma, Columbia University and the U.S. Geological Survey linked a 2011 swarm of earthquakes in Oklahoma to fracking

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[166] Fountain, H. (2013, December 12). Experts eye oil and gas industry as quakes shake Oklahoma. *The New York Times*. Retrieved June 9, 2014, from http://www.nytimes.com/2013/12/13/science/earth/as-quakes-shake-oklahoma-scientists-eye-oil-and-gas-industry.html

[167] Gillam, C. (2013, November 19). In Oklahoma, water, fracking - and a swarm of quakes. *Reuters*. Retrieved June 9, 2014, from http://www.reuters.com/article/2013/11/19/us-usa-earthquakes-fracking-oklahoma-idUSBRE9AI12W20131119

[168] Kim, W. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *Journal of Geophysical Research: Solid Earth, 118*(7), 3506-3518. doi: 10.1002/jgrb.50247

[169] Chameides, B. (2013, September 5). Fracking waste wells linked to Ohio earthquakes. *Scientific American*. Retrieved June 9, 2014, from http://www.scientificamerican.com/article/fracking-waste-wells-linked-to-ohio-earthquakes/

[170] Begley, S. (2013, July 11). Study raises new concern about earthquakes and fracking fluids. *Reuters*. Retrieved June 9, 2014, from http://www.reuters.com/article/2013/07/11/us-science-fracking-earthquakes-idUSBRE96A0TZ20130711

[171] Davies, R., Foulger, G., Bindley, A., & Styles, P. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. *Marine and Petroleum Geology, 45*, 171-185. doi: 10.1016/j.marpetgeo.2013.03.016.

waste disposal in that state.[172] This included a magnitude 5.7 earthquake—the largest ever triggered by wastewater injection—that injured two people, destroyed 14 homes, and was felt across 17 states.[173]

- December 14, 2012 – At a 2012 American Geophysical Union meeting, scientists presented data and concluded that some U.S. states, including Oklahoma, Texas and Colorado, have experienced a significant rise in seismic activity coinciding with a boom in gas drilling, fracking and wastewater disposal. Scientists further found that Oklahoma has seen a significant increase in earthquakes linked to wastewater injection, that a 5.3 earthquake in New Mexico was linked to wastewater injection, and that earthquakes were increasingly common within two miles of injection wells in the Barnett Shale region of Texas. Art McGarr, a researcher at the U.S. Geological Survey Earthquake Science Center, concluded that, "The future probably holds a lot more in induced earthquakes as the gas boom expands."[174]

- November 30, 2012, January 11, 2012, December 22, 2009 – In three sets of comments on proposed fracking guidelines and regulations, citing scientific reports linking oil and gas infrastructure to seismic activity, the NYC DEP raised serious concerns about the impacts of potential seismic activity from fracking-related activities on New York City's water supply infrastructure.[175] [176] [177] The NYC DEP has consistently raised concerns that seismic activity surrounding New York City's aquifers and watershed infrastructure could threaten the city's drinking water supply. For instance, DEP wrote that,

> *Given the similar geological mechanisms, the City has further investigated the risk that seismic activity from shale gas drilling poses to our tunnels and, based on that investigation, has concluded that the proposed protections do not go far enough to protect the integrity of the tunnels. Seismic activity from natural gas*

[172] Drajem, M., & Efstathiou, J., Jr. (2013, March 26). Quake tied to oil-drilling waste adds pressure for rules. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2013-03-26/oklahoma-earthquake-in-2011-tied-to-wastewater-wells-in-fracking.html

[173] Behar, M. (2013, March/April). Fracking's latest scandal? Earthquake swarms. *Mother Jones*. Retrieved June 9, 2014, from http://www.motherjones.com/environment/2013/03/does-fracking-cause-earthquakes-wastewater-dewatering?page=1

[174] Leber, J. (2012, December 14). Studies link earthquakes to wastewater from fracking. *MIT Technology Review*. Retrieved June 9, 2014, from http://www.technologyreview.com/news/508151/studies-link-earthquakes-to-wastewater-from-fracking/

[175] New York City Department of Environmental Protection. (2009, December 22). *New York City comments on: Draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program - Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs* (Rep.). Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_final_12-22-09.pdf

[176] New York City Department of Environmental Protection. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement* (Rep.). Retrieved June 11, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_on_rdsgeis_for_hvhf_20120111.pdf

[177] New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

> *drilling can be divided into two categories: hydraulic fracturing microseismicity and small induced earthquakes.* [178]

NYC DEP went on to discuss cases in Blackpool, England and Oklahoma, concluding that,

> *The Blackpool earthquakes and probably the Oklahoma earthquakes demonstrate that hydraulic fracturing fluids can reach a nearby fault and can trigger a seismic event. It should be noted that the natural gas wells in both of these cases were vertical, not horizontal, and neither well directly intercepted a fault. Nevertheless, the earthquakes generated were several miles away from the well. Horizontal wells, in contrast, have an even greater chance of directly intercepting a fault and, the distance from a well pad in which HVHF could reactivate a fault is therefore greater.... Thus, the RDSGEIS conclusion that induced seismic activity is not a significant impact is not supported by the evidence.*[179]

- September 6, 2012 – The British Columbia Oil and Gas Commission determined that fracking itself causes earthquakes, pointing to the results of a probe into 38 seismic events near fracking operations in the Horn River Basin. The report noted that no quakes had been recorded in the area prior to April, 2009, before fracking activities began. The report recommended that the link between fracking and seismic activity be further examined.[180]

- March 29, 2012 – The U.S. Geological Survey found that between 2001 and 2011, there was a six-fold increase in earthquakes greater than magnitude 3.0 in the middle of the United States that "are almost certainly manmade." The agency reported that the increase appears to be linked to oil and gas production and deep injection of drilling wastewater.[181] [182]

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[178]New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). 7. Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

[179] New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). 28. Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

[180] The Canadian Press. (2012, September 06). Fracking causes minor earthquakes, B.C. regulator says. *CBC News*. Retrieved June 9, 2014, from http://www.cbc.ca/news/canada/british-columbia/fracking-causes-minor-earthquakes-b-c-regulator-says-1.1209063

[181] Ellsworth, W. (2011, April 18). Are seismicity rate changes in the midcontinent natural or manmade? Retrieved June 9, 2014, from http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-sortfield=PresDay&-sortorder=ascending&-sortfield=Special+Session+Name+Calc&-sortorder=ascending&-sortfield=PresTimeSort&-sortorder=ascending&-op=gt&PresStatus=0&-lop=and&-token.1=ShowSession&-token.2=ShowHeading&-recid=224&-format=%2Fmeetings%2F2012%2Fabstracts%2Fsessionabstractdetail.html&-lay=MtgList&-find

[182] Soraghan, M. (2012, March 29). 'Remarkable' spate of man-made quakes linked to drilling, USGS team says. *E&E Publishing, LLC*. Retrieved June 11, 2014, from http://www.eenews.net/stories/1059962190

- July 31, 2011 – Numerous earthquakes in Arkansas motivated the Arkansas Oil and Gas Commission to shut down a disposal well and enact a permanent moratorium on future disposal wells in a nearly 1,200 square-mile area of the Fayetteville Shale.[183]

- March 10, 2010 – In Texas, a 2008-2009 swarm of earthquakes in the Dallas-Fort Worth area, where the Barnett Shale is being developed, was linked to produced water disposal wells.[184]

- June 12, 2009 – *The Wall Street Journal* reported that earthquakes shook Cleburne, Texas, a small town at the epicenter of fracking activity, including a number of earthquake clusters in the Dallas-Fort Worth area. The U.S. Geological Survey noted that more earthquakes were detected during that period of fracking activity than in the previous 30 years combined.[185]

Abandoned and active oil and natural gas wells (as pathways for gas and fluid migration)

- June 19, 2014 – A doctoral thesis (under review for journal publication) by a Princeton University engineering student suggests that abandoned oil and gas wells in Pennsylvania, left over from prior decades of conventional drilling, leak significantly more methane than previously thought. Between 280,000 and 970,000 abandoned oil and gas wells are located in Pennsylvania, and many go unchecked and unmonitored for leaks. Based on measurements from 19 such wells, the study estimated that the methane leaks from abandoned wells alone could account for between 4 and 13 percent of human-caused methane emissions in the state.[186] [187]

- December 1, 2013 – An analysis of reports from the NY DEC found that three-quarters of the state's abandoned oil and gas wells were never plugged. New York State has approximately 48,000 such wells; many of their locations remain unknown.[188]

- Aug. 4, 2011 – A report from the U.S. EPA to Congress in 1987—and discovered by *The New York Times*—concluded that abandoned natural gas wells may have served as a

[183] Zilk, C. (2011, July 31). Permanent disposal-well moratorium issued. *Arkansas Online*. Retrieved June 9, 2014, from http://www.arkansasonline.com/news/2011/jul/31/permanent-disposal-well-moratorium-issued-20110731/
[184] Frohlich, C., Hayward, C., Stump, B., & Potter, E. (2011). The Dallas-Fort Worth Earthquake Sequence: October 2008 through May 2009. *Bulletin of the Seismological Society of America, 101*(1), 327-340. doi: 10.1785/0120100131
[185] Casselman, B. (2009, June 12). Temblors rattle texas town. *The Wall Street Journal*. Retrieved June 9, 2014, from http://online.wsj.com/news/articles/SB124476331270108225
[186] Kang, M. (2014, June 17). CO2, Methane, and Brine Leakage Through Subsurface Pathways: Exploring Modeling, Measurement, and Policy Options. Princeton University Academic dissertations. Retrieved June 20, 2014, from http://arks.princeton.edu/ark:/88435/dsp019s1616326.
[187] Magill, B. (2014, June 19). Derelict Oil Wells May Be Major Methane Emitters | Climate Central. *Derelict Oil Wells May Be Major Methane Emitters | Climate Central*. Retrieved June 20, 2014, from http://www.climatecentral.org/news/abandoned-oil-wells-methane-emissions-17575
[188] Bishop, R. E. Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working?. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, 21, 103-116. Retrieved June 16, 2014, from http://baywood.metapress.com/media/16ut607yqg1yrw9ydad3/contributions/b/0/4/7/b047j34r87552325.pdf

pathway for hydraulic fracturing fluids to migrate underground from a shale gas well to a water well in West Virginia. In noting that the water well was polluted due to hydraulic fracturing and that such contamination was "illustrative" of contamination from oil and natural gas drilling, the report suggested that additional cases of groundwater contamination from hydraulic fracturing may exist.[189]

- April 4, 2011 – *ProPublica* reported that abandoned wells have caused problems across the nation including contamination of drinking water in Colorado, Kentucky, Michigan, New York, Texas and other states. *ProPublica* also found that a draft report from the Pennsylvania DEP described a 2008 incident in Pennsylvania in which a person died in an explosion triggered by lighting a candle in a bathroom after natural gas had seeped into a septic system from an abandoned well. The same draft report documented at least two dozen additional cases in which gas leaked from old wells, and three in which gas from new wells migrated into old wells, seeping into water supplies and requiring the evacuation of homes.[190]

- May 20, 2010 – The British Columbia Oil and Gas Commission issued a safety advisory after hydraulic fracturing caused a large "kick," or unintentional entry of fluid or gas, into a nearby gas well. The commission reported that it knew of 18 incidents in British Columbia and one in Western Alberta in which hydraulic fractures had entered nearby gas wells. "Large kicks resulted in volumes up to 80 cubic meters [about 100 cubic yards] of fluids produced to surface. Invading fluids have included water, carbon dioxide, nitrogen, sand, drilling mud, other stimulation fluids and small amounts of gas." These cases occurred in horizontal wells with a distance between wellbores of up to 2,300 feet. The Commission wrote, "It is recommended that operators cooperate through notifications and monitoring of all drilling and completion operations where fracturing takes place within 1000m [3,280 feet] of well bores existing or currently being drilled." Such communication between active wells raises the potential that similar communication can occur between active wells and abandoned wells.[191]

- 2010 – The NY DEC cautioned that "abandoned wells can leak oil, gas and/or brine; underground leaks may go undiscovered for years. These fluids can contaminate ground and surface water, kill vegetation, and cause public safety and health problems." As the agency reported, "DEC has at least partial records on 40,000 wells, but estimates that over 75,000 oil and gas wells have been drilled in the State since the 1820s. Most of the wells date from before New York established a regulatory program. Many of these old wells were never properly plugged or were plugged using older techniques that were less reliable and long-lasting than modern methods."[192] The NY DEC published similar

[189] Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. Retrieved June 11, 2014, from http://www.nytimes.com/2011/08/04/us/04natgas.html
[190] Kusnetz, N. (2011, April 4). Danger in honeycomb of old wells. *Pittsburgh Post-Gazette*. Retrieved June 11, 2014, from http://www.post-gazette.com/nation/2011/04/04/Danger-in-honeycomb-of-old-wells/stories/201104040149
[191] British Columbia Oil & Gas Commission. (2010, May 20). Safety advisory: communication during fracture stimulation. Retrieved July 3, 2014, from https://www.bcogc.ca/node/5806/download
[192] New York State Department of Environmental Conservation. (2014). New York oil, gas and mineral resources annual reports. Retrieved June 11, 2014, from http://www.dec.ny.gov/pubs/36033.html

comments in 2008 and 2009.

- January 2009 – Drilling industry consultant M.C. Vincent wrote an article published by the Society of Petroleum Engineers in which he reported that fractures from hydraulically fractured wells can intersect with nearby wells:

  > *Contrary to common expectations, there are numerous examples of fractures intersecting offset wells [existing oil or natural gas wells near the well being fractured] but subsequently providing little or no sustained hydraulic connection between the wells. There is an understandable reluctance to publish reports documenting the intersection of adjacent wellbores with hydraulic fractures. Such information could unnecessarily alarm regulators or adjacent leaseholders who may infer that well spacing or fracture treatments are allowing unexpected capture of reserves.*[193]

  Vincent added, "Although computing tools have improved, as an industry we remain incapable of fully describing the complexity of the fracture, reservoir, and fluid flow regimes." The article's findings raise the possibility that there could be similar communications between existing fracked wells that are fractured and abandoned wells and that operators cannot accurately predict how these will interact.

- 2005 – M.K. Fisher, vice president of Business Management at Pinnacle, a service of Halliburton that specializes in hydraulic fracturing, reported in an article published by the Society of Petroleum Engineers that a single fracture produced during a fracking operation in the Texas Barnett Shale had unexpectedly spread 2,500 feet laterally in two directions. He also described fractures in the Barnett Shale as "extremely complex."[194] These findings raise the possibility that well communication over very large distances could occur due to fractures that spread "unexpectedly."

- October 1999 – The U.S. Department of Energy reported that there were approximately 2.5 million abandoned oil and gas wells in the U.S.[195]

- Early 1990s – An underground waste disposal well in McKean County, Pennsylvania, contaminated groundwater when the wastewater traveled up a nearby abandoned, unmapped and unplugged oil well. Owners of private water wells that were contaminated in the incident eventually had to be connected to a public water system.[196]

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[193] Vincent, M. (2009, January 19). *Examining our assumptions – Have oversimplifications jeopardized our ability to design optimal fracture treatments?* Lecture presented at Society of petroleum engineers hydraulic fracturing technology conference in The Woodlands, Texas.

[194] Fisher, M., Wright, C., Davidson, B., Steinsberger, N., Buckler, W., Goodwin, A., & Fielder, E. (2005). Integrating Fracture-Mapping Technologies To Improve Stimulations in the Barnett Shale. *SPE Production & Facilities, 20*(2). doi: 10.2118/77441-PA

[195] United States Department of Energy, Office of Fossil Energy. (1999, October 5). *Environmental benefits of advanced oil and gas exploration and production technology* (Rep.). Retrieved June 11, 2014, from http://www.netl.doe.gov/kmd/cds/disk25/oilandgas.pdf

[196] Hopey, D. (2012, January 3). Wastewater disposal wells under scrutiny following Irvin leak. *Pittsburgh Post-Gazette*. Retrieved June 11, 2014, from http://www.post-gazette.com/news/environment/2012/01/03/Wastewater-disposal-wells-under-scrutiny-following-Irvin-leak.html

- July 1989 –In the past, the investigative agency for Congress, the U.S. General Accounting Office [now the Government Accountability Office] studied oil and natural gas underground injection disposal wells and found serious cases of contamination. The agency reported that, in several cases, wastewater from oil and natural gas operations had migrated up into abandoned oil and natural gas wells, contaminating underground water supplies. The GAO found that "if these abandoned wells are not properly plugged—that is, sealed off —and have cracked casings, they can serve as pathways for injected brines [waste fluids from natural gas and oil drilling] to enter drinking water….Because groundwater moves very slowly, any contaminants that enter it will remain concentrated for long periods of time, and cleanup, if it is technically feasible, can be prohibitively costly."[197]

- December 1987 – The EPA submitted a report to Congress on oil and natural gas wastes in which the agency cautioned:

> *… [T]o avoid degradation of ground water and surface water, it is vital that abandoned wells be properly plugged. Plugging involves the placement of cement over portions of a wellbore to permanently block or seal formations containing hydrocarbons or high-chloride waters (native brines). Lack of plugging or improper plugging of a well may allow native brines or injected wastes [from a waste fluid disposal well] to migrate to freshwater aquifers or to come to the surface through the wellbore. The potential for this is highest where brines originate from a naturally pressurized formation such as the Coleman Junction formation found in West Texas….Proper well plugging is essential for protection of ground water and surface water in all oil and gas production areas.*[198]

  While the EPA did not address the potential for contamination through abandoned wells as a result of hydraulic fracturing, both hydraulic fracturing and underground injection disposal wells require underground injection of fluid under pressure, raising the potential that there is a similar risk of groundwater contamination when hydraulic fracturing occurs near abandoned wells.

- 1985 – In an investigation of 4,658 complaints due to oil and natural gas production, the Texas Department of Agriculture found that "when a water well is experiencing an oilfield pollution problem (typically, high chlorides), the pollution source is often difficult to track down. The source could be a leak in the casing of a disposal well, leakage behind the casing due to poor cement bond, old saltwater evaporation pits, or, most often, transport of contaminants through an *improperly plugged abandoned well*" (emphasis in original). The agency found more than a dozen confirmed or suspected

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[197] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved June 10, 2014, from http://www.gao.gov/products/RCED-89-97. (2, 4, Rep.).

[198] U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). Retrieved June 11, 2014, from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.PDF. (III-47, Rep.),

cases in which pollutants had migrated up abandoned wells and contaminated groundwater. In one case, drilling wastewater migrated up an abandoned well a half mile away from where the wastewater was injected underground for disposal.[199]

- November 1978 – In a report later cited by the EPA in its 1987 report to Congress (cited above), the state of Illinois Environmental Protection Agency found that oil and natural gas wastes injected underground could migrate through abandoned oil and natural gas wells and contaminate groundwater. The agency wrote, "In old production areas, abandoned wells may pose a serious threat to ground water quality. Unplugged or improperly plugged wells provide possible vertical communication between saline and fresh water aquifers."[200]

Flood risks

- June 20, 2014 –*The Coloradoan* reported that Noble Energy storage tanks damaged by spring flooding in Colorado dumped 7,500 gallons of crude oil, fracking chemicals, and fracking wastewater into the Poudre River, which is both a National Heritage area and a habitat for Colorado's only self-sustaining population of wild trout. Recent high river flows had undercut the bank where the oil tank was located, which caused the tank to drop and break a valve.[201]

- September 2013 – An extraordinary flood that struck the Front Range of Colorado killed ten people, forced the evacuation of 18,000 more, destroyed more than 1850 homes, and damaged roads, bridges, and farmland throughout the state. More than 2650 oil and gas wells and associated facilities were also affected, with 1614 wells lying directly within the flood impact zone. Many of these storm-damaged facilities and storage tanks leaked uncontrollably. In a later accounting, Matt Lepore, director of the Colorado Oil and Gas Conservation Commission, estimated the flooding had resulted in the release to the environment of 48,250 gallons of oil or condensate and 43,479 gallons of fracking wastewater from 50 different spill sites across the state. In Colorado, more than 20,850 oil and gas wells lie within 500 feet of a river, stream, or other drainage. According to Commissioner Lepore, setback requirements that keep drilling and fracking operations away from residential areas inadvertently encourage operators to drill in unoccupied floodplains. At the same time, oil and gas operators prefer locations close to supplies of water for use in fracking. These twin factors result in a clustering of drilling and fracking operations in low-lying areas prone to catastrophic flooding.[202]

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[199] Texas Department of Agriculture, Department of Natural Resources. (1985). *Agricultural land and water contamination: From injection wells, disposal pits, and abandoned wells used in oil and gas production* (pp. 5, 12-15). Austin, TX: Dept. of Agriculture, Office of Natural Resources.

[200] Illinois Environmental Protection Agency, Water Quality Management Planning. (1978). *Illinois oil field brine disposal assessment* (pp. 44-45, Rep.).

[201] Handy, R. (2014, June 20). Crude oil spills into Poudre near Windsor. *The Coloradoan.* Retrieved June 23, 2014, from http://www.coloradoan.com/story/news/local/2014/06/20/crude-oil-spills-poudre-near-windsor/11161379/

[202] Lepore, M. (2014, March). "Lessons Learned" in the front range flood of September 2013: a staff report to the commissioners of the Colorado Oil and Gas Conservation Commission. Retrieved July 7, 2012, from the Colorado Oil and Gas Conservation Commission website: http://cogcc.state.co.us/Announcements/Hot_Topics/Flood2013/FinalStaffReportLessonsLearned20140314.pdf

- 2004-2013 – In at least six of the last ten years (2004, 2005, 2006, 2009, 2011 and 2013), several counties where shale gas drilling is most likely to occur in New York State have experienced serious flooding. These include the counties of Albany, Broome, Cattaraugus, Chautauqua, Chenango, Delaware, Erie, Greene, Madison, Orange, Otsego, Schoharie, Sullivan and Ulster. In at least five of the past 10 years (2004, 2005, 2006, 2009 and 20011), floods have exceeded 100-year levels in at least some of the counties.[203] [204] [205] [206] [207] [208] [209]

- February 7, 2013 – In its 2012 annual report to investors, oil and natural gas drilling company Noble Energy stated, "Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil and natural gas, including … flooding which could affect our operations in low-lying areas such as the Marcellus Shale."[210]

- September 7, 2011 – The NYS DEC's draft shale gas drilling plan recommended that drilling be prohibited within 100-year floodplains but acknowledged that many areas in the Delaware and Susquehanna River basins that were affected by flooding in 2004 and 2006 were located outside of officially designated flood zones.[211] In 2004, 2005, 2006, 2009 and 2011, flooding in New York exceeded 100-year levels in at least some of the counties where drilling and fracking may occur.

- 1992 – In its Generic Environmental Impact Statement (GEIS) for oil and natural gas drilling, the New York State DEC raised concerns that storage tanks holding drilling wastewater, spent hydraulic fracturing fluid or other contaminants could be damaged by flooding and leak. At the time, the GEIS called for at least some of these tanks to be

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[203] Brooks, L. T. (2005). *Flood of September 18-19, 2004 in the upper Delaware River basin, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://ny.water.usgs.gov/pubs/of/of051166/

[204] Suro, T. P., & Firda, G. D. (2006). *Flood of April 2–3, 2005, Neversink River basin, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/of/2006/1319/

[205] Suro, T. P., Firda, G. D., & Szabo, C. O. (2009). *Flood of June 26–29, 2006, Mohawk, Delaware and Susquehanna River basins, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/of/2009/1063/pdf/ofr2009-1063.pdf

[206] Szabo, C. O., Coon, W. F., & Niziol, T. A. (2010). *Flash floods of August 10, 2009, in the villages of Gowanda and Silver Creek, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/sir/2010/5259/pdf/SIR%202010-5259.pdf

[207] Szabo, L. (2011, September 8). *Remnants of Tropical Storm Lee cause record flooding in the Susquehanna River basin* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://ny.water.usgs.gov/leeindex.html

[208]Giordano, S. (2013, January 29). Several eastern counties in central New York under water after heavy flooding. *Syracuse Post-Standard*. Retrieved June 11, 2014, from http://www.syracuse.com/news/index.ssf/2013/06/several_eastern_counties_in_ce.html

[209] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-32, 33, Rep.).

[210] Noble Energy, Annual Report (Form 10-K) (Feb. 7, 2013) at 42.

[211] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-22, 2-32, 33, Rep.).

properly secured.[212] However, if horizontal high-volume hydraulic fracturing (HVHF) is approved, shale gas operations will require many more storage tanks for fracking fluids and wastewater than conventional drilling operations anticipated by the DEC twenty years ago. In 1992, the agency anticipated that oil and gas wells in the state would require between 20,000 and 80,000 gallons of fracking fluid.[213] As of 2011, the agency anticipated that HVHF shale gas wells will require between 2.4 and 7.8 million gallons of fluid.[214]

Threats to agriculture and soil quality

- May 4, 2014 – In an analysis of state data from Colorado, the *Denver Post* reported that fracking related to oil and gas drilling is putting soil quality and farmlands at risk due to significant amounts of toxic fluids penetrating the soil. According to the *Denver Post* 578 spills were reported in 2013, which means that, on average in the state, a gallon of toxic liquid penetrates soil every eight minutes. Eugene Kelly, professor of Soil and Crop Sciences at Colorado State University, said that the overall impact of the oil and gas boom "is like a death sentence for soil."[215]

- November 28, 2012 – In conjunction with the Food & Environment Reporting Network, *The Nation* reported that serious risks to agriculture caused by fracking are increasing across the country and linked these concerns to risks to human health.[216]

- January, 2012 – A study of gas drilling's impacts on human and animal health concluded that the drilling process may lead to health problems. The study reported and analyzed a number of case studies, including dead and sick animals in several states that had been exposed to drilling or hydraulic fracturing fluids, wastewater, or contaminated ground or surface water.[217] The researchers cited 24 cases in six states where animals and their owners potentially affected by gas drilling. In one case a farmer separated 96 head of cattle into three areas, one along a creek where fracking wastewater was allegedly dumped and the remainder in fields without access to the contaminated creek; the farmer

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[212] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (8-42, 8-43, 9-35, Rep.).

[213] New York State Department of Environmental Conservation. (1992). *Generic environmental impact statement on the oil, gas and solution mining regulatory program* (Rep.). Retrieved June 11, 2014, from http://www.dec.ny.gov/docs/materials_minerals_pdf/dgeisv1ch8.pdf (9-26, Rep.).

[214] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-8, Rep.).

[215] Finley, B. (2014, May 4). Colorado faces oil boom "death sentence" for soil, eyes microbe fix. *The Denver Post*. Retrieved June 11, 2014, from http://www.denverpost.com/environment/ci_25692049/colorado-faces-oil-boom-death-sentence-soil-eyes

[216] Royte, E. (2012, November 28). Fracking our food supply. *The Nation*. Retrieved June 11, 2014, from http://www.thenation.com/article/171504/fracking-our-food-supply

[217] Bamberger, M., & Oswald, R. E. (2012). Impacts of gas drilling on human and animal health. *New Solutions: A Journal of Environmental and Occupational Health Policy, 22*(1), 51-77. doi: 10.2190/NS.22.1.e

found that, of the 60 head exposed to the creek, 21 died and 16 failed to produce, whereas the unexposed cattle experienced no unusual health problems. In another case, a farmer reported that of 140 head of cattle that were exposed to fracking wastewater, about 70 died, and there was a high incidence of stillborn and stunted calves in the remaining cattle.[218]

- January 2011 – U.S. Forest Service researchers reported dramatic negative effects on vegetation caused by the drilling and fracking of a natural gas well in an experimental forest in northeastern West Virginia.[219] In June 2008, the researchers found browning of foliage near the well pad, a lack of ground foliage and that many trees nearby had dropped their foliage. They attributed these impacts to the loss of control of the well bore on May 29, 2008, which caused an aerial release of materials from the well. Trees showed no apparent symptoms the following summer.[220] However, the researchers also found "dramatic impacts on vegetation" where drilling and fracking wastewater had been sprayed on the land as a disposal technique following completion of the well. Just after the spraying of approximately 60,000 gallons of wastewater at the first disposal site, the Forest Service researchers found 115 damaged trees and other evidence of harm. This figure grew to 147 trees almost a year later.[221] At a second site, where about 20,000 gallons of wastewater was sprayed, the damage was less dramatic, yet the researchers still found "considerable leaf browning and mortality of young northern red oak seedlings."[222] The researchers concluded that the spraying of the drilling fluids resulted in an "extreme" dose of chlorides to the forest.[223]

- May 2010 – Pennsylvania's Department of Agriculture quarantined 28 cows in Tioga County after the animals wandered through a spill of drilling wastewater and may have ingested some of it. The Department was concerned that beef eventually produced from

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[218] Ramanujan, K. (2012, March 7). Study suggests hydrofracking is killing farm animals, pets. *Cornell Chronicle*. Retrieved June 11, 2014, from http://www.news.cornell.edu/stories/2012/03/reproductive-problems-death-animals-exposed-fracking

[219] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (1-4, Rep.).

[220] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (10-11, Rep.).

[221] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf . (11-15, Rep.)

[222] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (15, Rep.).

[223] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (17, Rep.).

the cows could be contaminated as a result of any exposure. In May 2011, only ten yearlings were still quarantined, but the farmer who owned the cows, Carol Johnson, told National Public Radio that of 17 calves born to the quarantined cows in the spring of 2011, only six survived, and many of the calves that were lost were stillborn. "They were born dead or extremely weak. It's highly unusual," she said, continuing, "I might lose one or two calves a year, but I don't lose eight out of eleven."[224]

- March 2010 – A Pennsylvania State Extension analysis of dairy farms in the state found a decline in the number of dairy cows in areas of the state where fracking was prevalent. Pennsylvania counties that had both more than 10,000 dairy cows and more than 150 Marcellus Shale wells experienced a 16-percent decline in dairy cows between 2007 and 2010.[225]

- April 28, 2009 – Seventeen cows in Caddo Parish, Louisiana died within one hour after apparently ingesting hydraulic fracturing fluids spilled at a well that was being fractured. "It seemed obvious the cattle had died acutely from an ingested toxin that had drained from the 'fracking' operation going on at the property," Mike Barrington, a state veterinarian said in a document obtained from the state Department of Environmental Quality by the *New Orleans Times-Picayune*.[226] [227]

Threats to the climate system

- May 15, 2014 – A recent review of existing data on lifecycle emissions of methane from natural gas systems concluded that, as a strategy for addressing climate change, natural gas is a "bridge to nowhere." The review found that, over a 20-year time frame, natural gas is as bad as or worse than coal and oil as a driver of climate change.[228] Referencing this review and other recent studies, *Bloomberg Business News* reported that the EPA has underestimated the impact of methane leakage resulting from the production transmission, and distribution of natural gas and is using outdated estimates of methane's

[224] Phillips, S. (2011, September 27). Burning questions: Quarantined cows give birth to dead calves. *StateImpact*. Retrieved June 11, 2014, from http://stateimpact.npr.org/pennsylvania/2011/09/27/burning-questions-quarantined-cows-give-birth-to-dead-calves/

[225] Penn State Extension. (2010, March). *Pennsylvania dairy farms and Marcellus shale, 2007–2010* (Rep.). Retrieved June 11, 2014, from Penn State website: http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PA%20Dairy%20Farms%20and%20Marcellus%202007%20to%202010.pdf

[226] Schleifstein, M. (2011, March 27). Haynesville natural gas field is the most productive in the U.S. *The Times-Picayune*. Retrieved June 11, 2014, from http://www.nola.com/politics/index.ssf/2011/03/haynesville_natural_gas_field.html.

[227] KSLA. (2009, April 28). Cows in Caddo Parish fall dead near gas well. *KSLA News*. Retrieved June 11, 2014, from http://www.ksla.com/Global/story.asp?S=10268585

[228] Howarth, R. W. (2014). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas [Abstract]. *Energy Science & Engineering*. doi: 10.1002/ese3.35

potency compared to more recent estimates from the Intergovernmental Panel on Climate Change (IPCC).[229]

- April 25, 2014 – A reassessment of the heat-trapping potential of greenhouse gases revealed that current methods of accounting underestimate the climate-damaging impact of methane pollution from all sources, including drilling and fracking operations.[230]

- April 14, 2014 – A study from researchers at Purdue University, NOAA, Cornell University, University of Colorado at Boulder and Pennsylvania State University, published in *Proceedings of the National Academy of Sciences* found very high levels of methane emissions above many wells being drilled at fracking sites in Pennsylvania. Levels were 100 to 1,000 times above the estimates of federal regulators, who have always assumed very low methane emissions as wells are drilled.[231] [232]

- February 26, 2014 – The United Nations' top environmental official—Achim Steiner, who heads the UN Environmental Programme (UNEP)—argued that the shale gas rush is 'a liability' in efforts to slow climate change and that a switch from coal to natural gas is delaying critical energy transition to renewables.[233]

- February 13, 2014 – A major study in *Science* by Stanford University, Massachusetts Institute of Technology and the U.S. Department of Energy found that methane leaks negate any climate benefits of natural gas as a fuel for vehicles, and that the EPA is significantly underestimating methane in the atmosphere.[234] Lead author Adam R. Brandt told *The New York Times*, "Switching from diesel to natural gas, that's not a good policy from a climate perspective."[235] This study also concluded that the national methane leakage rate is likely between 3.6 and 7.2 percent of production.

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[229] Childers, A. (2014, May 9). EPA underestimates fracking's impact on climate change. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2014-05-09/epa-underestimates-fracking-s-impact-on-climate-change.html

[230] Edwards, M.R. and Trancik, J.E. (2014). Climate impacts of energy technologies depend on emissions timing. *Nature Climate Change* 4: 348-352. doi: 10.1038/NCLIMATE2204

[231] Caulton, D. R., Shepson, P. B., Santoro, R. L., Sparks, J. P., Howarth, R. W., Ingraffea, A. R., ... Miller, B. R. (2014). Toward a better understanding and quantification of methane emissions from shale gas development. *Proceedings of the National Academy of Sciences of the United States of America*. doi: 10.1073/pnas.1316546111

[232] Banjeree, N. (2014, April 14). EPA drastically underestimates methane released at drilling sites. *Los Angeles Times*. Retrieved June 10, 2014, from http://www.latimes.com/science/sciencenow/la-sci-sn-methane-emissions-natural-gas-fracking-20140414,0,2417418.story

[233] Goldenberg, S. (2014, February 26). Achim Steiner: Shale gas rush 'a liability' in efforts slow climate change. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2014/feb/26/achim-steiner-shale-gas-rush-climate-change-energy

[234] Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Petron, G., Jordaan, S. M., ... Harriss, R. (2014). Methane leaks from North American natural gas systems. *Energy and Environment, 343*(6172), 733-735. doi: 10.1126/science.1247045

[235] Davenport, C. (2014, February 13). Study finds methane leaks negate benefits of natural gas as a fuel for vehicles. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2014/02/14/us/study-finds-methane-leaks-negate-climate-benefits-of-natural-gas.html?smid=tw-share

- January 15, 2014 – The *Guardian* reported that even a new a study by BP found that "Shale gas …. will not cause a decline in greenhouse gases" and will do little to cut carbon emissions.[236]

- December 30, 2013 – An analysis of fracking-related truck transportation in the Susquehanna River Basin, Pennsylvania found that greenhouse gas emissions from frack water and waste hauling operations were 70–157 metric tons of CO_2 equivalent per gas well.[237]

- November 11, 2013 – In a letter to California Governor Jerry Brown, twenty of the nation's top climate scientists warned that pro-fracking policies will worsen climate disruption and harm California's efforts to be a leader in reducing greenhouse gas emissions. The letter called on Governor Brown to place a moratorium on fracking.[238] On November 21, 2013, a group of Governor Brown's former policy and campaign advisors made a similar request in light of concerns about the effects of fracking on climate change and water pollution. [239]

- October 18, 2013 – A team of researchers from multiple institutions including Harvard, the University of Michigan and NOAA reported that methane emissions due to drilling activities in the south-central U.S. may be almost five times greater than reported by the world's most comprehensive methane inventory. "These results cast doubt on the US EPA's recent decision to downscale its estimate of national natural gas emissions by 25-30 percent," the authors wrote.[240] As *The New York Times* reported, "The analysis also said that methane discharges in Texas and Oklahoma, where oil and gas production was concentrated at the time, were 2.7 times greater than conventional estimates. Emissions from oil and gas activity alone could be five times greater than the prevailing estimate."[241]

- October 18, 2013 – A major study spearheaded by Stanford University's Energy Modeling Forum concluded that fracking and the shale gas revolution will have no long-

[236] Harvey, F., & Macalister, T. (2014, January 16). BP study predicts greenhouse emissions will rise by almost a third in 20 years. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/business/2014/jan/15/bp-predicts-greenhouse-emissions-rise-third?CMP=twt_gu

[237] Gilmore, K. R., Hupp, R. L., & Glathar, J. (2014). Transport of Hydraulic Fracturing Water and Wastes in the Susquehanna River Basin, Pennsylvania. *Journal of Environmental Engineering, 140*. doi: 10.1061/(ASCE)EE.1943-7870.0000810

[238] Rogers, P. (2013, November 12). Top climate scientists call for fracking ban in letter to Gov. Jerry Brown. *San Jose Mercury News*. Retrieved June 10, 2014, from http://www.mercurynews.com/ci_24509392/top-climate-scientists-call-fracking-ban-letter-gov

[239] McNary, S. (2013, November 21). Former advisors to Gov. Brown request fracking ban. *Southern California Public Radio*. Retrieved June 10, 2014, from http://www.scpr.org/blogs/politics/2013/11/21/15248/former-advisors-to-gov-brown-request-fracking-ban/

[240] Miller, S. M., Wofsy, S. C., Michalak, A. M., Kort, E. A., Andrews, A. E., Biraud, S. C., ... Sweeney, C. (2013). Anthropogenic emissions of methane in the United States. *Proceedings of the National Academy of Sciences, 110*(50), 20018-20022. doi: 10.1073/pnas.1314392110

[241] Wines, M. (2013, November 25). Emissions of methane in U.S. exceed estimates, study finds. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/11/26/us/emissions-of-methane-in-us-exceed-estimates-study-finds.html?_r=0

term climate benefit. The study brought together a working group of about 50 experts and advisors from companies, government agencies and universities, and modeling teams from 14 organizations. The study also found that build-out of infrastructure for fracking and natural gas will discourage efforts to conserve energy and boost efficiency. The study did not examine methane leaks in order to weigh in on the short-term climate impacts of natural gas.[242]

- October 11, 2013 – As reported in the *Guardian*, key climate scientists argued that the growth in fracking across the United States is hurting the United States' credibility on climate change.[243]

- October 2, 2013 – Updated measurements from the IPCC determined that methane is even worse for the climate than previously thought. The IPCC determined that methane is 34 times more potent as a greenhouse gas in the atmosphere than CO2 over a 100-year timeframe, and 86 times more potent over a 20-year timeframe.[244]

- September 27, 2013 – The IPCC formally embraced an upper limit on greenhouse gases for the first time, warning that the world will exceed those levels and face irreversible climatic changes in a matter of decades unless steps are taken soon to reduce emissions. The IPCC reported that humanity faces a "carbon budget"—a limit on the amount of greenhouse gases that can be produced by industrial activity before irreversible, damaging consequences—of burning about a trillion metric tons of carbon. The world is on track to hit that by around 2040 at the current rate of energy consumption.[245]

- August 12, 2013 – A *New Scientist* review of the science on fracking and global warming concluded that fracking could accelerate climate change rather than slow it.[246]

[242] Huntington, H. (2013). Changing the game? Emissions and market implications of new natural gas supplies. *Energy Modeling Forum, 1*. Retrieved June 10, 2014, from https://emf.stanford.edu/publications/emf-26-changing-game-emissions-and-market-implications-new-natural-gas-supplies.
[243] Magill, B. (2013, October 11). Fracking hurts US climate change credibility, say scientists. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2013/oct/11/fracking-us-climate-credibility-shale-gas
[244] Romm, J. (2013, October 2). More bad news for fracking: IPCC warns methane traps much more heat than we thought. *Climate Progress*. Retrieved June 10, 2014, from http://thinkprogress.org/climate/2013/10/02/2708911/fracking-ipcc-methane/
[245] Gillis, J. (2013, September 27). U.N. climate panel endorses ceiling on global emissions. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/09/28/science/global-climate-change-report.html?pagewanted=all
[246] Pearce, F. (2013, August 12). Fracking could accelerate global warming. *New Scientist*. Retrieved June 10, 2014, from http://www.newscientist.com/article/dn24029-fracking-could-accelerate-global-warming.html#.UpEWqsQ3uSo

- May 28, 2013 – A research team led by Jeff Peischl, an associate scientist at NOAA's Cooperative Institute for Research in Environmental Sciences, estimated that the methane leak rate from Los Angeles-area oil and gas operations was about 17 percent.[247] [248]

- May, 2013 – A group of scientists and journalists studying climate change, led by Eric Larson, a scientist with Princeton University and Climate Central, reported that the often-purported 50 percent climate advantage of natural gas over coal is unlikely to be achieved over the next three to four decades given methane leaks and other factors.[249] The 50 percent claim is based on the fact that natural gas produces half as much carbon dioxide when burned than coal, but it ignores the significant greenhouse gas impacts of methane leakage that occurs throughout the life-cycle of natural gas production, transmission and distribution.

- January 2, 2013 – A NOAA study found methane emissions from oil and gas fields in Utah to be as high as nine percent of production. These levels are considered extremely damaging to the climate.[250]

- November, 2012 – A review by the United Nations Environment Programme found that emissions from fracking, as well as other non-conventional natural gas extraction methods, could increase global warming in the short term and be comparable to coal over a 100-year timeframe.[251]

- November, 2012 – The International Energy Agency found that a large natural gas boom—even with improvements in place to reduce leakage—would eventually lead to greenhouse gas concentrations of 650 parts per million and a global temperature rise of 3.5 degrees Celsius, far exceeding the 2 degree Celsius limit which the Plan concedes is critical to avoid the most severe effects of climate change.[252]

- May 29, 2012 – The *Guardian* summarized a special report on natural gas by the International Energy Agency: "A 'golden age of gas' spurred by a tripling of shale gas from fracking and other sources of unconventional gas by 2035 will stop renewable energy in its tracks if governments do not take action."[253]

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[247] Peischl, J., Ryerson, T. B., Brioude, J., Aikin, K. C., Andrews, A. E., Atlas, E., ... Parrish, D. D. (2013). Quantifying sources of methane using light alkanes in the Los Angeles basin, California. *Journal of Geophysical Research: Atmospheres, 118*(10), 4974-4990. doi: 10.1002/jgrd.50413

[248] Ogburn, S. (2014, May 15). Solving the Case of California's Extra Methane. *Scientific American Global RSS*. Retrieved July 3, 2014, from http://www.scientificamerican.com/article/solving-the-case-of-californias-extra-machine/

[249] Larson, E. D. (2013). Natural gas & climate change. *Climate Central*. Retrieved June 10, 2014, from http://assets.climatecentral.org/pdfs/NaturalGas-and-ClimateChange.pdf

[250] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12-12. doi: 10.1038/493012a

[251] Global Environmental Alert Service. (2012). Gas fracking: Can we safely squeeze the rocks? United Nations Environmental Programme. Retrieved June 10, 2014, from http://www.unep.org/pdf/UNEP-GEAS_NOV_2012.pdf

[252], World Energy Outlook 2012, (November 2012). *Golden Rules for a Golden Age of Natural Gas—World Energy Outlook Special Report on Unconventional Gas*, International Energy Agency. Retrieved July 9, 2014, from http://www.iea.org/publications/freepublications/publication/name,27408,en.html.

[253] Harvey, F. (2012, May 29). 'Golden age of gas' threatens renewable energy, IEA warns. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2012/may/29/gas-boom-renewables-agency-warns

- February, 2012 – A study found that the carbon dioxide emitted from the burning of natural gas —even neglecting the impacts of methane leakage—contributes significantly to greenhouse gas emissions that are driving climate change.[254]

- February 7, 2012 – A NOAA study of Colorado gas fields measured methane emissions of about four percent, a significant percentage that could be very damaging to the climate.[255]

- December 29, 2011 – As reported by *The New York Times,* levels of methane in the atmosphere have been steadily rising since 2007—coinciding with the onset of the fracking boom and posing a serious threat to the Earth's climate.[256]

- October, 2011 – A study from the National Center for Atmospheric Research concluded that substituting the use of natural gas for coal will increase rather than decrease the rate of global warming for many decades.[257]

- July 6, 2011 – According to the U.S. Energy Information Administration and other research, significant amounts of methane are leaking from aging gas pipelines and infrastructure.[258]

- April, 2011 – A comprehensive analysis of the greenhouse gas footprint of natural gas from shale formations found that between 3.6 percent to 7.9 percent of the methane from natural gas production wells escapes into the atmosphere, rather than being combusted, thereby undermining any climate benefits of gas over coal as a source of energy.[259] [260]

Inaccurate jobs claims, increased crime rates, and threats to property value and mortgages

- May 27, 2014 – A *Bloomberg News* analysis of 61 shale drilling companies found that the economic picture of shale oil and gas is unstable. Shale debt has almost doubled over the last four years while revenue has gained just 5.6 percent. For the 61 companies in their analysis, *Bloomberg News* reported: "In a measure of the shale industry's financial burden, debt hit $163.6 billion in the first quarter." Further, *Bloomberg News* noted that drillers are caught in a bind because they must keep borrowing to pay for exploration needed to "offset steep production declines typical of shale wells…. For companies that

[254] Myhrvold, N. P., & Caldeira, K. (2012). Greenhouse gases, climate change and the transition from coal to low-carbon electricity. *Environmental Research Letters, 7*(1). doi: 10.1088/1748-9326/7/1/014019
[255] Tollefson, J. (2012, February 7). Air sampling reveals high emissions from gas field. *Nature*. Retrieved June 10, 2014, from http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982
[256] Gillis, J. (2011, December 29). The puzzle of rising methane. *The New York Times*. Retrieved June 10, 2014, from http://green.blogs.nytimes.com/2011/12/29/the-puzzle-of-rising-methane/
[257] Wigley, T. M. (2011). Coal to gas: The influence of methane leakage. *Climatic Change, 108*(3), 601-608. doi: 10.1007/s10584-011-0217-3
[258] McKenna, P. (2011, July 6). Thousands of gas leaks under Boston and San Francisco. *New Scientist*. Retrieved June 10, 2014, from http://www.newscientist.com/article/mg21128203.800-thousands-of-gas-leaks-under-boston-and-san-francisco.html#.UpEbbMQ3uSp
[259] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change, 106*(4), 679-690. doi: 10.1007/s10584-011-0061-5
[260] Howarth, R. W., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: Response to Cathles et al. *Climatic Change, 113*(2), 537-549. doi: 10.1007/s10584-012-0401-0

can't afford to keep drilling, less oil coming out means less money coming in, accelerating the financial tailspin."[261]

- May 5, 2014 – An Associated Press analysis found that traffic fatalities have spiked in heavily drilled areas of six states whereas most other roads in the nation have become safer even as population has grown. In North Dakota drilling counties, for instance, traffic fatalities have increased 350 percent.[262]

- April 16, 2014 – A comprehensive article in the *Albany Law Review* concluded that the risks inherent with fracking are not covered by homeowner's insurance, not fully insured by the oil and gas industry and threaten mortgages and property value.[263]

- April 2014 – A report by the Multi-State Shale Research Collaborative, "Assessing the Impacts of Shale Drilling: Four Community Case Studies," documented economic, community, government and human services impact of fracking on four rural communities. The study found that fracking led to a rapid influx of out-of-state workers and, although some new jobs were created, these were accompanied by additional costs for police, emergency services, road damage, and social services. In addition, increased rents, and a shortage of affordable housing accompanied the fracking boom. Unemployment rose after one county's "boom" ended and, in another county, stayed above the state average throughout. [264]

- March 27, 2014 – A report by researchers at Rand Corp. determined that each shale gas well in Pennsylvania causes between $5,400 and $10,000 in damage to state roads. The report did not calculate damage to local roads, which is also significant. Researchers used estimates of truck trips that are significantly below the number estimated for New York by the NYS DEC.[265] [266]

- February 15, 2014 – *The Los Angeles Times* detailed steep increases in crime that have accompanied fracking in parts of the Eagle Ford Shale in Texas, including sexual assaults

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[261] Loder, A. (2014, May 27). Shakeout threatens shale patch as frackers go for broke. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2014-05-26/shakeout-threatens-shale-patch-as-frackers-go-for-broke.html

[262] Begos, K., & Fahey, J. (2014, May 5). AP impact: Deadly side effect to fracking boom. *Associated Press*. Retrieved June 10, 2014, from http://bigstory.ap.org/article/ap-impact-deadly-side-effect-fracking-boom-0

[263] Radow, E.L. (2014). At the Intersection of Wall Street and Main: Impacts of Hydraulic Fracturing on Residential Property Interests, Risk Allocation, and Implications for the Secondary Mortgage Market. *Albany Law Review* 77(2) 673-704.

[264] Multi-State Shale Research Collaborative. (2014, April 10). *Assessing the impacts of shale drilling county case studies* (Rep.). Retrieved June 10, 2014, from https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtdWx0aXN0YXRlc2hhbGV8Z3g6NGU4MjIyNWU5ZjFhZjM4Yg

[265] Cusick, M. (2014, March 27). Report finds each Marcellus gas well costs thousands in road damage. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/pennsylvania/2014/03/27/report-finds-each-marcellus-gas-well-costs-thousands-in-road-damage/

[266] Abramzon, S., Samaras, C., Curtright, A., Litovitz, A., & Burger, N. (2014). Estimating the consumptive use costs of shale natural gas extraction on Pennsylvania roadways. *Journal of Infrastructure Systems*. Retrieved June 10, 2014, from http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29IS.1943-555X.0000203

and thefts.[267]

- February 14, 2014 –Pennsylvania landowners with fracking leases rallied in Bradford County against gas companies for precipitous drops in royalty payments.[268]

- December 20, 2013 – The National Association of Realtors' *RealtorMag* summarized a growing body of research showing that fracking and gas drilling threaten property values, including a University of Denver survey and a *Reuters* analysis.[269]

- December 12, 2013 – A *Reuters* analysis discussed how oil and gas drilling has made making some properties "unsellable" and researched the link between drilling and property value declines. The analysis highlighted a Duke University working paper that finds shale gas drilling near homes can decrease property values by an average of 16.7 percent if the house depends on well water.[270]

- December 10, 2013 – Pennsylvania's *The Daily Review* reported that more gas companies are shifting costs to leaseholders and that royalty payments are drastically shrinking. The story quoted Bradford County commissioner Doug McLinko saying that some gas companies "are robbing our landowners" and that the problem of royalty payments being significantly reduced by deductions for post-production costs "is widespread throughout our county."[271]

- November 30, 2013 – *The New York Times* reported striking increases in crime in Montana and North Dakota where the oil and gas boom is prevalent, as well as challenges faced by local residents from the influx of out-of-area workers and the accompanying costs. The *New York Times* reported, "'It just feels like the modern-day Wild West,' said Sgt. Kylan Klauzer, an investigator in Dickinson, in western North Dakota. The Dickinson police handled 41 violent crimes last year, up from seven only five years ago."[272]

- November 21, 2013 – The Multi-State Shale Research Collaborative released a six-state collaborative report demonstrating that the oil and gas industry has greatly exaggerated

[267] Hennessy-Fiske, M. (2014, February 15). Fracking brings oil boom to south Texas town, for a price. Retrieved June 10, 2014, from http://www.latimes.com/nation/la-na-texas-oil-boom-20140216%2C0%2C7621618.story#ixzz30Iw9FXoz.
[268] Marshall, J. (2014, February 14). Landowners rally for royalties from gas companies. Retrieved June 10, 2014, from http://www.wbng.com/news/local/Landowners-rally-for-245596511.html
[269] Daily Real Estate News. (2013, December 20). 'Fracking' sparks concern over nearby home values. *National Association of Realtors*. Retrieved June 10, 2014, from http://realtormag.realtor.org/daily-news/2013/12/20/fracking-sparks-concern-over-nearby-home-values#.UrmdIlPmVu8.twitter
[270] Conlin, M. (2013, December 12). Gas drilling is killing property values for some Americans. *Reuters*. Retrieved June 10, 2014, from http://www.businessinsider.com/drilling-can-make-some-properties-unsellable-2013-12#ixzz2nMgFv8FU
[271] Loewenstein, J. (2013, December 10). Shrinking royalty checks. *Thedailyreview.com*. Retrieved June 10, 2014, from http://thedailyreview.com/news/shrinking-royalty-checks-1.1598195
[272] Healy, J. (2013, November 30). As oil floods plains towns, crime pours in. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/12/01/us/as-oil-floods-plains-towns-crime-pours-in.html?smid=tw-share&_r=0

the number of jobs created by drilling and fracking in shale formations. The report found that far from the industry's claims of 31 direct jobs created per well, only four jobs are created for each well. It also demonstrated that almost all of the hundreds of thousands of 'ancillary' jobs that the drilling industry claims are related to shale drilling existed before such drilling occurred. As Frank Mauro, executive director of the Fiscal Policy Institute put it, "Industry supporters have exaggerated the jobs impact in order to minimize or avoid altogether taxation, regulation, and even careful examination of shale drilling."[273]

- November 12, 2013 – *The American Banker* reported that the "Fracking Boom Gives Banks Mortgage Headaches," with a number of financial institutions refusing to make mortgages on land where oil and gas rights have been sold to an energy company. The article stated that the uniform New York state mortgage agreement used by Fannie Mae and Freddie Mac requires that homeowners not permit any hazardous materials to be used or located on their property. Fracking is therefore a problem because it is just such a hazardous activity with use of hazardous materials.[274]

- September 25, 2013 – A report found that fracking is linked to significant road damage, increased truck traffic, crime, and strain on municipal and social services. Data from the past ten years on the social costs of fracking including truck accidents, arrests, and higher rates of sexually transmitted diseases are all causes for alarm.[275]

- September 12, 2013 – In a feature titled "Pa. fracking boom goes bust," *The Philadelphia Inquirer* presented data from the independent Keystone Research Center detailing "flat at best" job growth and declines in production and royalty payments.[276]

- August 22, 2013 – A University of Denver study in the *Journal of Real Estate Literature* found a 5 percent to 15 percent reduction in bid value for homes near gas drilling sites. [277]

[273] Campbell, J. (2013, November 21). Report: Industry-backed studies exaggerate fracking job estimates. *Politics on the Hudson*. Retrieved June 10, 2014, from http://polhudson.lohudblogs.com/2013/11/21/report-industry-backed-studies-exaggerate-fracking-job-estimates/

[274] Peters, A. (2013, November 12). Fracking boom gives banks mortgage headaches. *American Banker*. Retrieved June 10, 2014, from http://www.americanbanker.com/issues/178_218/fracking-boom-gives-banks-mortgage-headaches-1063561-1.html

[275] Gibbons, B. S. (2013, September 25). Environmental groups calculate social cost of natural gas boom. *The Times-Tribune*. Retrieved June 10, 2014, from http://thetimes-tribune.com/news/environmental-groups-calculate-social-cost-of-natural-gas-boom-1.1558186

[276] Bunch, W. (2013, September 12). Pa. fracking boom goes bust. *Philly.com*. Retrieved June 10, 2014, from http://articles.philly.com/2013-09-12/news/41974274_1_fracking-boom-penn-state-marcellus-center-marcellus-shale

[277] Downing, B. (2013, April 22). Survey says home values hurt by fracking at drill sites. *Ohio.com*. Retrieved June 10, 2014, from http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/survey-says-home-values-hurt-by-fracking-at-drill-sites-1.422838

- August 21, 2013 – *The Atlantic Cities* and *MSN Money* reported that fracking operations may be damaging property values and may impair mortgages or the ability to obtain property insurance.[278] [279]

- August 13, 2013 – A *ProPublica* investigative analysis found that Chesapeake Energy is coping with its financial difficulties in Pennsylvania by shifting costs to landowners who are now receiving drastically reduced royalty payments.[280]

- August 4, 2013 – In a survey of West Virginia landowners with shale wells on their property, more than half reported problems including damage to the land, decline in property values, truck traffic and lack of compensation by the oil and gas company.[281]

- May 24, 2013 – Pennsylvania Department of Transportation Secretary Allen D. Biuhler, P.E., and Pennsylvania State Police Commissioner Frank Pawlowski said that gas drilling has led to increases in truck traffic, traffic violations, crime, demand for social services, and the number of miles of roads that are in need of repairs. They noted that drilling companies that committed to repairing roads have not kept pace with the roads they damage. Police Commissioner Pawlowski reported that 56 percent of 194 trucks checked were over the legal weight limit and 50 percent were also cited for safety violations. [282]

- May 4, 2013 – Pennsylvania's *Beaver County Times* asked "What boom?" in pointing to Keystone Research Center data showing that the number of jobs numbers created by shale gas extraction do not add up to what the gas industry claims, noting that unemployment has increased and the state actually fell to 49th in the nation for job creation.[283]

- April 2, 2013 – *The New York Times* reported that manufacturing jobs resulting from an abundance of shale gas have not appeared. "The promised job gains, other than in the petrochemical industry, have been slow to materialize," the *New York Times* reported.

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[278] Drouin, R. (2013, August 19). How the fracking boom could lead to a housing bust. *Citylab*. Retrieved June 10, 2014, from http://www.theatlanticcities.com/politics/2013/08/how-fracking-boom-could-lead-housing-bust/6588/

[279] Notte, J. (2013, August 21). Fracking leaves property values tapped out. *MSN Money*. Retrieved June 10, 2014, from http://money.msn.com/now/post--fracking-leaves-property-values-tapped-out

[280] Lustgarten, A. (2013, August 13). Unfair share: How oil and gas drillers avoid paying royalties. *ProPublica*. Retrieved June 10, 2014, from http://www.propublica.org/article/unfair-share-how-oil-and-gas-drillers-avoid-paying-royalties

[281] Collins, A. R., & Nkansah, K. (2013, August 4). *Divided rights, expanded conflict : The impact of split estates in natural gas production* [Scholarly project]. Retrieved June 10, 2014, from http://ageconsearch.umn.edu/bitstream/150128/2/Collins_Nkahsah_Split%20estate.pdf

[282] PR Newswire. (2014, May 24). Increased gas drilling activities bringing new challenges to local governments in Pennsylvania. *PR Newswire*. Retrieved June 10, 2014, from http://www.prnewswire.com/news-releases/increased-gas-drilling-activities-bringing-new-challenges-to-local-governments-in-pennsylvania-94774764.html

[283] Morgan, R. (2013, May 4). Beaver County Times: What boom? Industry pundits claim thousands of jobs will be created, but numbers don't quite add up. *Keystone Research Center*. Retrieved June 10, 2014, from http://keystoneresearch.org/media-center/media-coverage/beaver-county-times-what-boom-industry-pundits-claim-thousands-jobs-will

The article suggested that increased automation has made it unlikely that manufacturers will add many jobs.[284]

- March 19, 2013 – The *Wall Street Journal* reported that the shale gas boom has not had a big impact on U.S. manufacturing because lower energy prices are only one factor in a company's decision on where to locate factories, and not always the most important factor. "Cheap energy flowing from the U.S. shale-gas boom is often touted as a 'game changer' for manufacturing," the *Journal* reported. "Despite the benefits of lower energy costs, however, the game hasn't changed for most American manufacturers."[285]

- February, 2013 – A peer-reviewed analysis of industry-funded and independent studies on the economics of fracking found that it is unlikely that fracking will lead to long-term economic prosperity for communities. The analysis noted that shale gas development brings a number of negative externalities including the potential for water, air and land contamination; negative impacts on public health; wear and tear on roads and other infrastructure; and costs to communities due to increased demand for services such as police, fire departments, emergency responders, and hospitals.[286]

- November 16, 2012 – A Duke University study showed a drop in home values near fracking for properties that rely on groundwater. [287]

- September 27, 2012 – *The New York Times* reported that the prospect of fracking has hindered home sales in the Catskills and raised concerns about drops in property values, according to real estate agents and would-be buyers.[288]

- August 17, 2012 – A study by the state agencies, the Montana All Threat Intelligence Center and the North Dakota State and Local Intelligence Center, found that crime rose by 32 percent since 2005 in communities at the center of the oil and gas boom.[289]

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[284] Schwartz, N. D. (2013, April 01). Rumors of a cheap-energy jobs boom remain just that. *The New York Times*. Retrieved June 11, 2014, from http://www.nytimes.com/2013/04/02/business/economy/rumors-of-a-cheap-energy-jobs-boom-remain-just-that.html?_r=0

[285] Hagerty, J. R. (2013, March 19). Shale-gas boom alone won't propel U.S. industry. *The Wall Street Journal*. Retrieved June 10, 2014, from http://online.wsj.com/news/articles/SB10001424127887324392804578362781776519720

[286] Barth, J. M. (2013). The Economic Impact of Shale Gas Development on State and Local Economies: Benefits, Costs, and Uncertainties. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 85-101. doi: 10.2190/NS.23.1.f

[287] Muoio, D. (2012, November 16). Duke researchers show dip in home value caused by nearby fracking. *The Chronicle*. Retrieved June 10, 2014, from http://www.dukechronicle.com/articles/2012/11/16/duke-researchers-show-dip-home-value-caused-nearby-fracking

[288] Navarro, M. (2012, September 27). Gas drilling jitters unsettle catskills sales. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/09/30/realestate/fracking-fears-hurt-second-home-sales-in-catskills.html?pagewanted=1

[289] Montana All Threat Intelligence Center, & North Dakota State and Local Intelligence Center. (2012, August 17). *Impact of population growth on law enforcement in the Williston Basin region* (Rep.). Retrieved June 10, 2014, from http://www.ag.nd.gov/reports/JOINTPRODUCTFINAL.pdf

- October 30, 2011 – A comprehensive article in the *New York State Bar Association Journal* concluded that the risks inherent with fracking threaten mortgages.[290]

- October 26, 2011 – The Associated Press reported that areas with significant fracking activity, including Pennsylvania, Wyoming North Dakota and Texas, are "seeing a sharp increase in drunken driving, bar fights and other hell-raising."[291]

- October 19, 2011 – A *New York Times* investigation found that fracking can create conflicts with mortgages, and that "bankers are concerned because many leases allow drillers to operate in ways that violate rules in landowners' mortgages," and further that "[f]earful of just such a possibility, some banks have become reluctant to grant mortgages on properties leased for gas drilling. At least eight local or national banks do not typically issue mortgages on such properties, lenders say."[292]

- September 7, 2011 – The NYS DEC estimated that 77 percent of the workforce on initial shale gas drilling projects would consist of transient workers from out of state. Not until the thirtieth year of shale gas development would 90 percent of the workforce be comprised of New York residents.[293]

- August 15, 2011 – The *Pittsburgh Post-Gazette* reported that increases in crime followed the Pennsylvania gas drilling boom, noting, for instance, that drunken driving arrests in Bradford County were up 60 percent, DUI arrests were up 50 percent in Towanda, and criminal sentencing was up 35 percent in 2010.[294]

- July 26, 2011 – A New York State Department of Transportation document estimated that fracking in New York could result in the need for road repairs and reconstruction costing $211 million to $378 million each year.[295]

- June 20, 2011 – A Keystone Research Center study found that the gas industry's claim of 48,000 jobs created between 2007 and 2010 as a result of natural gas drilling in

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[290] Radow, E. N. (2011). Homeowners and gas drilling leases: Boon or bust? *New York State Bar Association Journal, 83*(9). Retrieved June 10, 2014, from http://www.s-oacc.org/resources/NYSBA_Journal_nov-dec2011_lead_article_with_reprint_info.pdf

[291] Levy, M. (2011, October 26). Towns see crime, carousing surge amid gas boom. *Associated Press*. Retrieved June 10, 2014, from http://news.yahoo.com/towns-see-crime-carousing-surge-amid-gas-boom-135643480.html

[292] Urbina, I. (2011, October 19). A rush to sign leases for gas runs into mortgage restriction. *The New York Times*. Retrieved June 11, 2014, from http://www.nytimes.com/2011/10/20/us/rush-to-drill-for-gas-creates-mortgage-conflicts.html?_r=2&hp&

[293] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-233, 234, Rep.).

[294] Needles, Z. (2011, August 15). Must crime follow Pennsylvania's gas drilling boom? *Pittsburgh Post-Gazette*. Retrieved June 10, 2014, from http://www.post-gazette.com/stories/business/legal/must-crime-follow-pennsylvanias-gas-drilling-boom-310373/

[295] Reilly, S. (2011, July 26). Document estimates fracking's toll on N.Y. roads. *Pressconnects.com*. Retrieved June 10, 2014, from http://www.pressconnects.com/article/20110726/NEWS01/107260384/Document-estimates-fracking-s-toll-N-Y-roads

Pennsylvania is a far cry from the actual number of only 5,669 jobs—many of which were out-of-state hires.[296]

- May 9, 2011 – A study in the *Journal of Town & City Management* found that shale gas development can impose "significant short- and long-term costs" to local communities. The study noted that shale gas development creates a wide range of potential environmental hazards and stressors, all of which can adversely impact regional economies, including tourism and agriculture sectors.[297]

- November 30, 2010 – The *Dallas Morning News* featured a story, "Drilling Can Dig into Land Value," reporting that the Wise County Central Appraisal District Appraisal Review Board found that a drilling company had caused an "extraordinary reduction" in property value, by 75 percent.[298]

- November 28, 2010 – The Texas' *Wise County Messenger* reported that some landowners near fracking operations experience excessive noise, exposure to diesel fumes, and problems with trespassing by workers.[299]

Inflated estimates of oil and gas reserves and profitability

- April 10, 2014 – A report by a petroleum geologist and petroleum engineer concluded the 100-year supply of shale gas is a myth, distinguished between what is technically recoverable and economically recoverable shale gas, and asserted that at current prices, New York State has no economically recoverable shale gas.[300]

- February 28, 2014 – The chief of the International Energy Agency reported that there is only a decade left in the US shale oil and gas boom, noting that the growth would not last and that production would soon flatten out and go down.[301]

- December 18, 2013 – A University of Texas study in *Proceedings of the National Academy of Sciences* found that fracking well production drops sharply with time, which

[296] Herzenberg, S. (2011). Drilling deeper into job claims. *Keystone Research Center*. Retrieved June 10, 2014, from http://keystoneresearch.org/sites/keystoneresearch.org/files/Drilling-Deeper-into-Jobs-Claims-6-20-2011_0.pdf
[297] Christopherson, S., & Rightor, N. (2011). How shale gas extraction affects drilling localities: Lessons for regional and city policy makers. *Journal of Town & City Management, 2*(4), 1-20. Retrieved June 10, 2014, from http://www.greenchoices.cornell.edu/downloads/development/shale/Economic_Effects_on_Drilling_Localities.pdf
[298] Heinkel-Wolfe, P. (2010, September 18). Drilling can dig into land value. *Dallas News*. Retrieved June 10, 2014, from http://www.dallasnews.com/incoming/20100918-Drilling-can-dig-into-land-value-9345.ece
[299] Evans, B. (2010, November 28). Rising volume: 'Fracking' has bolstered economies, but noise still echoes around drilling. *WCMessenger.com*. Retrieved June 10, 2014, from http://www.wcmessenger.com/2010/news/rising-volume-fracking-has-bolstered-economies-but-noise-still-echoes-around-drilling/
[300] Labyrinth Consulting Services, Inc., Berman, A., and Pittinger, L. (2014). Resource Assessment of Potentially Producible Natural Gas Volumes From the Marcellus Shale, State of New York. Retrieved from: http://www.lwvny.org/
[301] Unger, D. J. (2014, February 28). IEA chief: Only a decade left in US shale oil boom. *The Christian Science Monitor*. Retrieved June 10, 2014, from http://www.csmonitor.com/Environment/Energy-Voices/2014/0228/IEA-chief-Only-a-decade-left-in-US-shale-oil-boom

undercuts the oil and gas industry's economic projections.[302] In an interview about the study with *StateImpact NPR* in Texas, Tad Patzek, chair of the Department of Petroleum and Geosystems Engineering at University of Texas at Austin, noted that fracking "also interferes now more and more with daily lives of people. Drilling is coming to your neighborhood, and most people abhor the thought of having somebody drilling a well in their neighborhood."[303]

- August 18, 2013 – *Bloomberg News* reported that low gas prices and disappointing wells have led major companies to devalue oil and gas shale assets by billions of dollars.[304]

- October 21, 2012 – *The New York Times* reported that many gas drilling companies overproduced natural gas backed by creative financing and now "are committed to spending far more to produce gas than they can earn selling it." "We are all losing our shirts today," said Exxon CEO Rex Tillerson in the summer of 2012.[305]

- July 13, 2012 – The *Wall Street Journal* reported that ITG Investment Research, at the request of institutional investors, evaluated the reserves of Chesapeake Energy Corp.'s shale gas reserves in the Barnett and Haynesville formations and found them to be only 70 percent of estimates by Chesapeake's engineering consultant for the company's 2011 annual report. Chesapeake and its consultant defended their figures.[306]

- August 23, 2011 – The U.S. Geological Survey cut the government's estimates of natural gas in the Marcellus Shale from 410 trillion cubic feet to 84 trillion cubic feet, equivalent to a reduction from approximately 16 years of U.S. consumption at current levels of natural gas use, to approximately 3.3 years of consumption. The U.S. Geological Survey's updated estimate was for natural gas that is technically recoverable, irrespective of economic considerations such as the price of natural gas or the cost of extracting it.[307]

- June 26-27, 2011 – As reported in two *New York Times* stories, hundreds of emails, internal documents, and analyses of data from thousands of wells from drilling industry employees combined with documents from federal energy officials raised concerns that shale gas companies were overstating the amount of gas in their reserves and the

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[302] Patzek, T. W., Male, F., & Marder, M. (2013). Gas production in the Barnett Shale obeys a simple scaling theory. *Proceedings of the National Academy of Sciences, 110*(49), 19731-19736. doi: 10.1073/pnas.1313380110

[303] Buchele, M. (2013, December 18). New study shows how gas production from "fracked" wells slows over time. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/texas/2013/12/18/new-study-shows-how-gas-production-from-fracked-wells-slows-over-time/

[304] Monks, M., Penty, R., & De Vynck, G. (2013, August 18). Shale grab in U.S. stalls as falling values repel buyers. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2013-08-18/shale-grab-in-u-s-stalls-as-falling-values-repel-buyers.html

[305] Krauss, C., & Lipton, E. (2012, October 20). After the boom in natural gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/10/21/business/energy-environment/in-a-natural-gas-glut-big-winners-and-losers.html?pagewanted=all

[306] Wirz, M. (2013, July 13). Chesapeake reserve doubted. *The Wall Street Journal*. Retrieved June 10, 2014, from http://online.wsj.com/news/articles/SB10001424052702303644004577523411723501548

[307] United States Geological Survey. (2011, August 23). USGS releases new assessment of gas resources in the Marcellus shale, Appalachian Basin. *USGS Newsroom*. Retrieved June 10, 2014, from http://www.usgs.gov/newsroom/article.asp?ID=2893&from=rss_home#.Uok0mGRO_GA.

profitability of their operations.[308] [309] [310] The *New York Times*' public editor criticized the stories, but offered no evidence that the major findings were wrong.[311] The *New York Times*' news editors publicly defended both stories against the public editor's criticism.[312] [313]

Disclosure of serious risks to investors

A snapshot of the dangers posed by natural gas drilling and fracking pose can be found in an annual Form 10-K that oil and natural gas companies are required to disclose annually to the U.S. Securities and Exchange Commission (SEC). Federal law requires that companies offering stock to the public disclose in their Form 10-K, among other things, the "most significant factors that make the offering speculative or risky."[314]

In a review of the most recent Form 10-Ks available on the SEC's website, oil and natural gas companies routinely warned of drilling's serious risks. In the words of Exxon Mobil Corp.'s subsidiary XTO Energy Corp., these included "hazards and risks inherent in drilling"[315]; or in the language of Range Resources Corp., "natural gas, NGLs [natural gas liquids] and oil operations are subject to many risks."[316]

Such hazards and risks include leaks, spills, explosions, blowouts, environmental damage, property damage, injury and death. Chesapeake Energy Corporation, which has been interested in drilling in New York, has stated that "horizontal and deep drilling activities involve greater risk of mechanical problems than vertical and shallow drilling

[308] Urbina, I. (2011, June 25). Insiders sound an alarm amid a natural gas rush. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/06/26/us/26gas.html?pagewanted=all
[309] U.S. Energy Information Administration. (2014, May 30). U.S. Natural Gas Summary. Retrieved June 10, 2014, from http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm
[310] Urbina, I. (2011, August 24). Geologists sharply cut estimate of shale gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/08/25/us/25gas.html
[311] Brisbane, A. S. (2011, July 16). Clashing views on the future of natural gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/07/17/opinion/sunday/17pubed.html?gwh=7D408242717755A0E06B0D265498E177&gwt=pay&assetType=opinion&_r=0
[312] Brisbane, A. S. (2011, July 17). Times editors respond to my shale gas column. *The New York Times*. Retrieved June 10, 2014, from http://publiceditor.blogs.nytimes.com/2011/07/17/times-editors-respond-to-my-shale-gas-column/
[313] Brisbane, A. S. (2011, July 30). Times editors respond to column on redactions. *The New York Times*. Retrieved June 10, 2014, from http://publiceditor.blogs.nytimes.com/2011/07/30/times-editors-respond-to-column-on-redactions/
[314] See 17 C.F.R. § 229.503(c) (companies must disclose the "most significant" risks); 17 C.F.R. § 230.405 ("the term material, when used to qualify a requirement for the furnishing of information as to any subject, limits the information required to those matters to which there is a substantial likelihood that a reasonable investor would attach importance in determining whether to purchase the security registered"); 17 C.F.R. § 240.10b-5 (it is illegal "to make any untrue statement of a material fact or to omit to state a material fact . . . in connection with the purchase or sale of any security); 17 C.F.R. 249.310 (requiring Form 10-K, "for annual and transition reports pursuant to sections 13 or 15(d) of the Securities Exchange Act of 1934.")
[315] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 25.
[316] Range Resources, Corp., Annual Report (Form 10-K) (Feb. 27, 2013) at 23.

operations."[317] Companies want to use horizontal drilling and fracking to extract shale gas in New York State.

The companies also routinely warn of inadequate insurance to cover drilling harms. XTO Energy Corporation, which holds thousands of acres of natural gas leases in New York, states that "we are not fully insured against all environmental risks, and no coverage is maintained with respect to any penalty or fine required to be paid by us."[318]

Houston-based Noble Energy provides a representative example of the risks that at least several drilling companies include in their annual reports. Noble states:

> *Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil and natural gas, including:*
>
> - *injuries and/or deaths of employees, supplier personnel, or other individuals;*
> - *pipeline ruptures and spills;*
> - *fires, explosions, blowouts and well cratering;*
> - *equipment malfunctions and/or mechanical failure on high-volume, high-impact wells;*
> - *leaks or spills occurring during the transfer of hydrocarbons from an FPSO to an oil tanker;*
> - *loss of product occurring as a result of transfer to a rail car or train derailments;*
> - *formations with abnormal pressures and basin subsidence;*
> - *release of pollutants;*
> - *surface spillage of, or contamination of groundwater by, fluids used in hydraulic fracturing operations;*
> - *security breaches, cyber attacks, piracy, or terroristic acts;*
> - *theft or vandalism of oilfield equipment and supplies, especially in areas of increased activity such as the DJ Basin and Marcellus Shale;*
> - *hurricanes, cyclones, windstorms, or "superstorms," such as Hurricane Sandy which occurred in 2012, which could affect our operations in areas such as the Gulf Coast, deepwater Gulf of Mexico, Marcellus Shale, Eastern Mediterranean or offshore China;*
> - *winter storms and snow which could affect our operations in the Rocky Mountain areas;*
> - *unseasonably warm weather, which could affect third party gathering and processing facilities, such as occurred in the Rocky Mountain areas during 2012;*
> - *volcanoes which could affect our operations offshore Equatorial Guinea;*
> - *flooding which could affect our operations in low-lying areas such as the Marcellus Shale;*
> - *harsh weather and rough seas offshore the Falkland Islands, which could limit certain exploration activities; and*
> - *other natural disasters.*

[317] Chesapeake Energy Corp., Annual Report (Form 10-K) (Mar. 1, 2013) at 21.
[318] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 17.

Any of these can result in loss of hydrocarbons, environmental pollution and other damage to our properties or the properties of others.[319]

Noble has language similar to that found in other companies' annual reports about inadequate insurance and adds, "coverage is generally limited or not available to us for pollution events that are considered gradual."[320]

The risks identified by Noble and other drilling companies are not just hypothetical. Many, if not all of these risks have become realities as illustrated in the other sections of this compendium.

Medical and scientific calls for more study and more transparency

- June 30, 2014 – In a letter to the Pennsylvania Department of Environmental Protection, director of the Mid-Atlantic Center for Children's Health and the Environment, Jerome A. Paulson, MD, called for industry disclosure of all ingredients of fracking fluid; thorough study of all air contaminants released from drilling and fracking operations and their protected dispersal patterns; and study and disclosure of fracking-related water contamination and its mechanisms. Dr. Paulson said:

  > *In summary, neither the industry, nor government agencies, nor other researchers have ever documented that [unconventional gas extraction] can be performed in a manner that minimizes risks to human health. There is now some evidence that these risks that many have been concerned about for a number of years are real risks. There is also much data to indicate that there are a number of toxic chemicals used or derived from the process, known or plausible routes of exposure of those chemicals to humans; and therefore, reason to place extreme limits on [unconventional gas extraction]*[321].

- June 20, 2014 – Highlighting preliminary studies in the United States that suggest an increased risk of adverse health problems among individuals living within ten miles of shale gas operations, a commentary in the British medical journal *The Lancet* called for a precautionary approach to gas drilling in the United Kingdom. According the commentary, "It may be irresponsible to consider any further fracking in the UK (exploratory or otherwise) until these prospective studies have been completed and the health impacts of fracking have been determined."[322]

- June 20, 2014 – Led by an occupational and environmental medicine physician, a Pennsylvania-based medical and environmental science research team documented "… the substantial concern about adverse health effects of [unconventional natural gas development] among Pennsylvania Marcellus Shale residents, and that these concerns

[319] Noble Energy, Annual Report (Form 10-K) (Feb. 7, 2013) at 41-42.
[320] Noble Energy. Annual Report (Form 10-K) (Feb 7, 2013) at 41-42.
[321] Paulson, J.A. (2014, June 30). http://concernedhealthny.org/letter-from-dr-jerome-a-paulson-to-the-pennsylvania-department-of-environmental-protection/.
[322] Hill, M. (2014, June 20). Shale gas regulation in the UK and health implications of fracking. *The Lancet*. Early Online Publication, doi:10.1016/S0140-6736(14)60888-6

may not be adequately represented in medical records." The teams identified the continued need to pursue environmental, clinical and epidemiological studies to better understand associations between fracking, medical outcomes, and residents' ongoing concerns.[323]

- June 17, 2014 – A discussion paper by the Nova Scotia Deputy Chief Medical Officer and a panel of experts identified potential economic benefits as well as public health concerns from unconventional oil and gas development. On the health impacts, they wrote, "uncertainties around long term environmental effects, particularly those related to climate change and its impact on the health of both current and future generations, are considerable and should inform government decision making." The report noted potential dangers including contamination of groundwater, air pollution, surface spills, increased truck traffic, noise pollution, occupational health hazards and the generation of greenhouse gases. It also noted that proximity of potential fracking sites to human habitation should give regulators pause and called for a health impact assessment and study of long-term impacts.[324] Responding to the report, the Environmental Health Association of Nova Scotia applauded the go-slow approach and called for a 10-year moratorium on fracking.[325]

- May 29, 2014 – In New York State, more than 250 medical organizations and health professionals released a letter detailing emerging trends in the data on fracking that show significant risk to public health, air quality, water, as well as other impacts. With signatories including the American Academy of Pediatrics, District II, the American Lung Association in New York, Physicians for Social Responsibility, and many leading researchers examining the impacts of fracking, they wrote, "The totality of the science — which now encompasses hundreds of peer-reviewed studies and hundreds of additional reports and case examples—shows that permitting fracking in New York would pose significant threats to the air, water, health and safety of New Yorkers."[326] [327]

- May 9, 2014 – In a peer-reviewed analysis, leading toxicologists outlined some of the potential harm and uncertainty relating to the toxicity of the chemical and physical agents associated with fracking, individually and in combination. While acknowledging the need for more research and greater involvement of toxicologists, they noted the potential for

[323] Saberi, P., Propert, K.J., Powers, M. Emmett, E. and Green-McKenzie, J. (2014). Field Survey of Health Perception and Complaints of Pennsylvania Residents in the Marcellus Shale Region. *International Journal of Environmental Research and Public Health* 11(6), 6517-6527.
[324] Atherton, F. (2014, June 17). Discussion Paper: Hydraulic Fracturing and Public Health in Nova Scotia . Nova Scotia Hydraulic Fracturing Independent Review and Public Engagement Process.
[325] Macdonald, M. (2014, June 17). Nova Scotia expert calls for go-slow approach for hydraulic fracturing. *The Canadian Press*. Retrieved June 20, 2014, from http://www.calgaryherald.com/health/Health+studies+needed+hydraulic+fracturing+approved+Nova+Scotia/9946368/story.html
[326] Concerned Health Professionals of NY. (2014, May 29). Letter to Governor Cuomo and acting Health Commissioner Zucker [Letter to Governor Andrew M. Cuomo & Acting Health Commissioner Howard A. Zucker]. New York City, New York.
[327] Hughes, K. (2014, May 29). NY fracking opponents call for moratorium of 3 to 5 years. *Daily Freeman*. Retrieved June 11, 2014, from http://www.dailyfreeman.com/general-news/20140529/ny-fracking-opponents-call-for-moratorium-of-3-to-5-years

surface and groundwater contamination from fracking, growing concerns about air pollution particularly in the aggregate, and occupational exposures that pose a series of potential hazards to worker health.[328] [329]

- May 1, 2014 – A 292-page report from a panel of top Canadian scientists urged caution on fracking, noting that it poses "the possibility of major adverse impacts on people and ecosystems" and that significantly more study is necessary to understand the full extent of the risks and impacts.[330] The *Financial Post* reported that the panel of experts "found significant uncertainty on the risks to the environment and human health, which include possible contamination of ground water as well as exposure to poorly understood combinations of chemicals."[331]

- April 30, 2014 – Medical professionals spoke out on the dearth of public health information collected and lack of long-term study five years into Pennsylvania's fracking boom. Walter Tsou, MD, MPH, of Physicians for Social Responsibility and former health commissioner of Philadelphia commented, "That kind of study from a rigorous scientific perspective has never been done." Other experts added, "There has been more health research involving fracking in recent years, but every study seems to consider a different aspect, and…there is no coordination." [332]

- April 17, 2014 – In the preeminent *British Medical Journal*, authors of a commentary, including an endocrinologist and a professor of clinical public health, wrote, "Rigorous, quantitative epidemiological research is needed to assess the risks to public health, and data are just starting to emerge. As investigations of shale gas extraction in the US have continually suggested, assurances of safety are no proxy for adequate protection."[333]

- April 15, 2014 – The *Canadian Medical Association Journal* reported on the increasing legitimacy of concerns about fracking on health: "While scientists and area residents have been sounding the alarm about the health impacts of shale gas drilling for years, recent

[328] Society of Toxicology. (2014). Toxicologists outline key health and environmental concerns associated with hydraulic fracturing. *ScienceDaily*. Retrieved June 11, 2014, from http://www.sciencedaily.com/releases/2014/05/140509172545.htm

[329] Goldstein, B. D., Brooks, B. W., Cohen, S. D., Gates, A. E., Honeycutt, M. E., Morris, J. B., ... Snawder, J. (2014). The role of toxicological science in meeting the challenges and opportunities of hydraulic fracturing [Abstract]. *Toxicological Sciences, 139*(2). doi: 10.1093/toxsci/kfu061

[330] The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction. (2014). Environmental Impacts of Hurricane Mitch. *Council of Canadian Academies*. Retrieved June 11, 2014, from http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/shale%20gas/shalegas_fullreporten.pdf

[331] Canadian Press. (2014, May 1). Top Canadian scientists urge cautious approach to fracking until more known of impact. *Financial Post*. Retrieved June 11, 2014, from http://business.financialpost.com/2014/05/01/top-canadian-scientists-urge-cautious-approach-to-fracking-until-more-known-of-impact/?__lsa=3b44-76a1

[332] Khan, N. (2014, April 30). Health impact of gas fracking left in the dark. *Pocono Record*. Retrieved June 11, 2014, from http://www.poconorecord.com/apps/pbcs.dll/article?AID=/20140430/NEWS90/404300301/-1/NEWS01

[333] Law, A., Hays, J., Shonkoff, S. B., & Finkel, M. L. (2014). Public Health England's draft report on shale gas extraction [Abstract]. *BMJ, 1840*. doi: http://dx.doi.org/10.1136/bmj.g2728

studies, a legal decision and public health advocates are bringing greater legitimacy to concerns."[334]

- March 3, 2014 – In the *Medical Journal of Australia*, researchers and a physician published a strongly worded statement, "Harms unknown: health uncertainties cast doubt on the role of unconventional gas in Australia's energy future." They cited knowledge to date on air, water, and soil pollution, and expressed concern about "environmental, social and psychological factors that have more indirect effects on health, and important social justice implications" yet to be understood. They wrote in summary:

  > *The uncertainties surrounding the health implications of unconventional gas, when considered together with doubts surrounding its greenhouse gas profile and cost, weigh heavily against proceeding with proposed future developments. While the health effects associated with fracturing chemicals have attracted considerable public attention, risks posed by wastewater, community disruption and the interaction between exposures are of also of concern*.[335]

- March 1, 2014 – In the prestigious British medical journal *The Lancet*, researchers summarized workshops and research about the health impacts of fracking:

  > *Scientific study of the health effects of fracking is in its infancy … but findings suggest that this form of extraction might increase health risks compared with conventional oil and gas wells because of the larger surface footprints of fracking sites [due to the large number of well pads being developed]; their close proximity to locations where people live, work, and play; and the need to transport and store large volumes of materials.*[336]

- February 24, 2014 – In a review of the health effects of unconventional natural gas extraction published in the journal *Environmental Science & Technology*, leading researchers identified a range of impacts and exposure pathways that can be detrimental to human health. Noting how fracking disrupts communities, the review states, "For communities near development and production sites the major stressors are air pollutants, ground and surface water contamination, truck traffic and noise pollution, accidents and malfunctions, and psychosocial stress associated with community change." They concluded, "Overall, the current scientific literature suggests that there are both substantial public concerns and major uncertainties to address." [337]

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[334] Glauser, W. (2014). New legitimacy to concerns about fracking and health. *Canadian Medical Association Journal, 186*(8), E245-E246. doi: 10.1503/cmaj.109-4725

[335] Coram, A., Moss, J., & Blashki, G. (2014). Harms unknown: Health uncertainties cast doubt on the role of unconventional gas in Australia's energy future. *The Medical Journal of Australia, 200*(4), 210-213. doi: 10.5694/mja13.11023

[336] Kovats, S., Depledge, M., Haines, A., Fleming, L. E., Wilkinson, P., Shonkoff, S. B., & Scovronick, N. (2014). The health implications of fracking. *The Lancet, 383*(9919), 757-758. doi: 10.1016/S0140-6736(13)62700-2

[337] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es404621d

- August 30, 2013 – A summary of a 2012 workshop by the Institute of Medicine Roundtable on Environmental Health Sciences, Research, and Medicine featured various experts who discussed health and environmental concerns about fracking and the need for more research. The report in summary of the workshop stated, "The governmental public health system, which retains primary responsibility for health, was not an early participant in discussions about shale gas extraction; thus public health is lacking critical information about environmental health impacts of these technologies and is limited in its ability to address concerns raised by regulators at the federal and state levels, communities, and workers employed in the shale gas extraction industry."[338]

- April 22, 2013 – In one of the first peer-reviewed nursing articles summarizing the known health and community risks of fracking, Professor Margaret Rafferty, Chair of the Department of Nursing at New York City College of Technology wrote, "Any initiation or further expansion of unconventional gas drilling must be preceded by a comprehensive Health Impact Assessment (HIA)." [339]

- May 10, 2011 - In the *American Journal of Public Health*, two medical experts cautioned that fracking "poses a threat to the environment and to the public's health. There is evidence that many of the chemicals used in fracking can damage the lungs, liver, kidneys, blood, and brain." The authors urged that it would be prudent to invoke the precautionary principle in order to protect public health and the environment.[340]

Conclusion

All together, the findings from the scientific, medical, and journalistic investigations indicate that fracking poses significant threats to air, water, health, public safety, and long-term economic vitality. Concerned both by the rapidly expanding evidence of harm and by the fundamental data gaps still remaining, Concerned Health Professionals considers a moratorium on unconventional oil and natural gas extraction (fracking) the only appropriate and ethical course of action while scientific and medical knowledge on the impacts of fracking continues to emerge.

[338] Coussens, C., & Martinez, R. (2013). *Health impact assessment of shale gas extraction: workshop summary*. Washington: THE NATIONAL ACADEMIES PRESS. Retrieved June 16, 2014, from http://www.iom.edu/Reports/2013/Health-Impact-Assessment-of-Shale-Gas-Extraction.aspx

[339] Rafferty, M. A., & Limonik, E. (2013). Is Shale Gas Drilling an Energy Solution or Public Health Crisis? *Public Health Nursing, 30*(5), 454-462. doi: 10.1111/phn.12036

[340] Law, A. The Rush to Drill for Natural Gas: A Public Health Cautionary Tale. *American Journal of Public Health*, 101, 784-785. Retrieved June 16, 2014, from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3076392/