APPENDIX I – ANALYSIS OF CONCERNS AND RISKS OF HORIZONTAL DRILLING AND HYDRAULIC FRACTURING

This Appendix contains two documents used in the analysis of the availability of gas leasing. The first document is "*Specific Concerns with Gas Development and Actions to Address the Concerns.*" The second document is "*A Review of the Concerns and Risks of Improper Implementation of Mitigation Measures for Horizontal Drilling and Hydraulic Fracturing*."

PART I: SPECIFIC CONCERNS WITH GAS DEVELOPMENT AND ACTIONS TO ADDRESS THE CONCERNS

The Forest Interdisciplinary Team reviewed public comments and information on gas drilling to develop a specific list of potential impacts and actions that can be used to reduce the potential for those impacts to occur.

1. Effects of water withdrawals on surface and groundwater supplies and on wetlands
   - Flow reduction in streams and aquifers can impact water quality (for example: temperature, dissolved oxygen, chemistry).
   - Flow reduction in streams and aquifers can impact water quantity available for aquatic organism habitat, especially during summer and fall when flows are generally low.
   - Water withdrawal structures can result in entrainment and impingement of aquatic organisms.
   - Transporting water can transfer invasive species from one waterbody to another via trucks, hoses, pipelines, and other equipment.
   - Aquifer depletion from either surface or groundwater pumping.
   - Aquifer depletion leading to decline in groundwater level and effect on nearby streams, rivers, and wetlands that are connected to groundwater.
   - Hydrologic changes to wetlands can negatively affect wetland plants and animals.

Actions needed to address the concern:

a. Modify standard11-043 under Riparian Corridors as follows:

   The riparian corridors are suitable for federal oil and gas leasing with a controlled surface use stipulation to protect riparian resources and values. *Roads, pipelines, and utilities associated with access to lease operations may be allowed to cross riparian areas. Well pads and associated well development infrastructure are not allowed in riparian areas.* Other Federal minerals may be available on a case-by-case basis after full consideration of effects on the riparian corridor.

b. Modify standard 11-044 under Riparian Corridors as follows:

   ~~Federal oil and gas leases exist within these corridors.~~ *On existing Federal oil and gas leases,* roads, ~~wells, and other necessary infrastructure~~ *pipelines, and utilities* associated with *access to lease operations may be* ~~these leases are~~ *allowed to cross riparian areas. Well pads and associated well development infrastructure are not allowed in riparian areas.* Existing lease terms and stipulations are used to protect the riparian corridor.

c. Add forestwide standard under Minerals and Geologic Resources as follows:

   The Forest Service will only approve Surface Use Plans of Operations associated with Applications for Permit to Drill that contain the following provisions:

   1) Water will not be withdrawn from surface water or groundwater sources on the Forest unless a qualified Forest Service employee determines that this withdrawal will result in less overall environmental impacts than the impacts of not withdrawing the water;
   2) Only closed loop systems will be used for hydraulic fracturing;
   3) Drill cuttings will be removed from the drill site and disposed of at approved sites off the Forest, unless authorized by qualified Forest Service employee;

4) Secondary containment infrastructure will be used at the site to reduce impacts from stormflow or spills;
5) No surface disposal of flowback water or produced waters will be allowed on the National Forest;
6) Non-native invasive species occurring at the site of new openings constructed in association with drilling activities will be treated as long as the well is under lease.

2. Effects of accidental spills on soils and water during drilling phase and stimulation phase

- Contamination of surface water bodies and groundwater resources from ineffective site management and surface and subsurface fluid containment practices.
- Contamination of surface water bodies and groundwater resources from accidental spills and releases (from tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or improper operations).
- Contamination of surface water bodies and groundwater resources from spilled, leaked, or released fluids, pit leakage or failure.
- Greater intensity and duration of surface activities associated with well pads with multiples wells increases the odds of an accidental spill if mitigation measures are not sufficiently durable.
- What are the monitoring capabilities and response times for emergency responses to accidents? What is the onsite presence during operations? How long can accidents continue before they are identified and mitigated?

Actions needed to address the concern:

a. Modify current riparian standards 11-043 and 11-044 as shown in Concern 1.
b. Identify Public Water Supply Watersheds as not suitable for leasing to reduce potential for any accidental spills from affecting water supplies. In addition, include the watersheds upstream of the Public Water Supply Watersheds on the Pedlar River and Dry River since they are the only water supplies surrounded by National Forest System lands that do not extend to include the entire watershed.
c. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.
d. Disclosure of chemicals used (See Concern 15).
e. BLM and the Forest Service will utilize best available information (such as the Gold Book, appropriate standards and best practices for hydraulic fracturing identified by the American Petroleum Institute, Onshore Oil & Gas Order No. 2) in preparing conditions of approval for the APD and in preparing the Surface Use Plan.
f. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

3. Groundwater contamination during drilling or fracking operations

- Contamination of surface water bodies and groundwater resources from poor casing construction and grouting.
- Flowback components include gelling agents, surfactants, chlorides, dissolved solids, metals, biocides, lubricants, organics and radionuclides (water containing tens of thousands of pounds of chemicals, salt, and sand) that can contaminate surface and groundwater.
- Not knowing the composition of the fracking fluids used on the site.
- Millions of gallons of contaminated flowback water remaining in the ground during and after production, or stored in injection wells.
- Corrosive agents used in fracking fluid could eventually erode casings (even the extra steel and concrete required in wells to protect groundwater) and contaminate entire aquifers.
- Earthquakes could crack concrete casings causing contamination of aquifers.
- Shale deposits adjacent to limestone geology where residual frac water under pressure could find its way into karst water, potentially affecting fragile aquatic karst biota.
- Potential effects of concentrated solids, contaminated with radioactive wastes (radium), extracted from the ground following shale fracture.

- Potential effects of natural gas contamination of drinking water.
- Water quality monitoring before, during and after activity, including adjacent private wells.

Actions needed to address the concern:

a. Identify Public Water Supply Watersheds as in Concern 2.
b. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.
c. Disclosure of chemicals used (See Concern 15).
d. Utilize best available information as in Concern 2.
e. Forest Plan strategy should identify that the Forest will encourage companies to monitor any private drinking water wells located within 1,000 feet of wells drilled on the Forest.
f. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

4. Water contamination from improper treatment of flowback water

- Proper design, construction, operation, closure, and regulatory oversight of centralized flowback water surface impoundments and pipelines.
  - Flowback water dilution and reuse system has environmental benefits, including reduced demand for fresh water, reduced truck traffic, and reduced need for flowback water treatment and disposal.
- Contaminated flowback that is trucked off site may not be able to be effectively treated, and a mixture of sand, salt, biocides, surfactants, lubricants, and solvents could pass directly into rivers.
- Management of drill cuttings and other solid waste materials.
- Land application of contaminated flowback and solids could sterilize soil, kill vegetation, and enter surface and groundwater.
  - At the very least, flowback water is known to contain high levels of chloride, which has a number of biological and non-biological effects, passing readily through soil and will eventually enter surface or ground water.

Actions needed to address the concern:

a. Identify Public Water Supply Watersheds as in Concern 2.
b. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.
c. There are no authorized underground injection wells for waste disposal on the Forest. These wells are regulated by EPA. Any approval of such a well would be subject to NEPA through a process separate from the forest planning process.
d. Disclosure of chemicals used (See Concern 15).
e. Utilize best available information as in Concern 2.
f. Treatment of any flowback waters would be subject to State requirements for treatment since these fluids would not be allowed to be disposed on the Forest.
g. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

5. Contamination of surface or groundwater from stormwater during operations

- Contamination of surface water bodies and groundwater resources from failure to maintain storm-water controls.
- Water resource impacts if storm water is not properly managed during all phases of well development (land clearing, access roads, equipment staging areas, well pads, drilling and fracturing operations, production and final reclamation).
  - Land clearing exposes soil to erosion and more rapid runoff.
  - Steep access roads, well pads on hill slopes, and well pads constructed by cut-and-fill operations pose particular challenges to stabilizing soil.
  - Equipment fluids (hydraulic fluid, fuel, and lubricating fluids) and any materials that are spilled are exposed to rainfall and contaminants may be conveyed off-site during rain events.
  - Greater potential for storm water impacts from a larger well pad during the production phase, compared with a smaller well pad for a single vertical well.

Actions needed to address the concern:

a. Modify current riparian standards 11-043 and 11-044 as in Concern 1.
b. Identify Public Water Supply Watersheds as in Concern 2.
c. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.
d. Disclosure of chemicals used (See Concern 15).
e. Utilize best available information as in Concern 2.
f. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

6. Pit or surface impoundment leakage or failure affecting vegetation and water quality

- Wastewater flowback water stored in holding ponds or onsite tanks, potentially adjacent to perennial or intermittent stream channels, subject to overflow, leakage, or spillage, causing fish kills, affecting aquatic food webs, or drinking water.
- Additional potential of releases from hoses or pipes used to convey flowback water to tanks, an on-site pit, a centralized surface impoundment, or a tanker truck for transportation to a treatment or disposal site.
- Heightened concern if on-site pits are constructed on the filled portion of a cut-and-filled well pad.
- Additional potential of releases from tank leakage or failure of a pit or surface impoundment to effectively contain fluid.
- Soil, wetland, surface water and groundwater contamination from spills, leaks, or other failure of the impoundment to effectively contain fluid.
  - Including problems associated with liner or construction defects, unstable ballast, or operation-related liner damage.
- Soil, wetland, surface water and groundwater contamination from spills or leaks of hoses or pipes used to convey flowback water to or from the centralized surface impoundment.
- Physical damage similar to that from dam failure if a breach occurs.
- Lethal and sub-lethal effects to biota that use the impoundment (mammals, birds, amphibians, reptiles, insects etc.)

Actions needed to address the concern:

a. Modify current riparian standards 11-043 and 11-044 as in Concern 1.
b. Identify Public Water Supply Watersheds as in Concern 2.
c. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.
d. Disclosure of chemicals used (See Concern 15).
e. Utilize best available information as in Concern 2.
f. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors

7. Roads and other surface disturbance increasing non-point source pollution

- Sediment effects from the large number of trucks on roads, especially if usage continues in any weather, any season.
- Fugitive dust contamination into nearby or adjacent waterways.

Actions needed to address the concern:

a. Modify current riparian standards 11-043 and 11-044 as in Concern 1.
b. Identify Public Water Supply Watersheds as in Concern 2.
c. Utilize best available information as in Concern 2.
d. Utilize Forest Plan standards regarding roads and sediment.
e. Add a forestwide standard under Minerals and Geologic Resources as follows:
   Generally pipelines associated with development of natural gas resources will be constructed within road corridors.

8. Impact of the creation of openings on the spread of non-native invasive species

Actions needed to address the concern:

a. Utilize forestwide standards related to non-native invasive plants.
b. Add a forestwide standard under Minerals and Geologic Resources as in Concern 1.

9. Effects of new roads and drilling activities on semi-primitive recreation settings, increased probability of encounters with others, public safety with increased truck traffic, wildlife, hunting and other recreation users

Actions needed to address the concern:

a. These impacts can be addressed through conditions of approval of the surface use plan and application for permit to drill. Time of year restrictions can be used, as can use of technology to shield nighttime lighting. Approval of road locations can also influence the extent of these impacts.
b. Public safety based on site specific plans for truck traffic and road use would be part of conditions of approval of the APD.
c. Federal Onshore Oil & Gas Operations Order No. 1 requires: "The operator must improve or maintain existing roads in a condition the same as or better than before operations began...When access involves use of existing roads, the FS may require that the operator contribute to road maintenance."

10. Impacts of drilling operations, road construction, well pad construction and operations on Special Biological Areas

Actions needed to address the concern:

a. Identify Special Biological Areas, Shenandoah Crest and Key Natural Heritage Community Areas as suitable for leasing only with NSO to prevent impacts to the sensitive biological communities in these areas.
b. Identify the area above 3,000 feet in elevation on Shenandoah Mountain south of Highway 250 as suitable for leasing only with NSO due to the known presence of Cow Knob salamander.
c. Identify the Indiana bat secondary protection areas as suitable for leasing only with NSO to reduce impacts to the bat.

11. Effects of drilling and well stimulation on caves and karst resources

Actions needed to address the concern:

a. Identify geologic areas and the Indiana bat primary protection areas as suitable for leasing only with NSO to reduce potential for any impacts on caves and karst resources.
b. Utilize best available information as in Concern 2.
c. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

12. Impacts on scenery of the new roads and the equipment installations

Actions needed to address the concern:

a. Any restrictions on locations of drill sites and roads in relation to scenic resources would be addressed as conditions of approval of the Surface Use Plan associated with the APD.
b. Utilize best available information as in Concern 2.

13. Potential impacts on earthquakes from well development activities

Actions needed to address the concern:

a. There are no underground injection wells on the Forest.

14. Impacts on air quality from well development

Actions needed to address the concern:

a. Operations will be subject to current EPA air quality regulations.
b. Utilize best available information as in Concern 2.
c. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

15. Impacts of the chemicals used in drilling and well stimulation on Forest Service employees and Forest users

Actions needed to address the concern:

a. Add a new forestwide standard under a new section titled Material Safety as follows:
Any commercial operator proposing to work under the following Forest Service issued authorizations or approvals (concessionaire permit, timber contract, range allotment, Surface Use Plan of Operation under an Application for Permit to Drill, special use permit) must, upon request, provide information about materials proposed to be brought onto, stored on, or left on National Forest System lands. This information would include Material Safety Data Sheets (MSDS) sheets as well as identification of materials marked, labeled or placarded in accordance with the U. S. Department of Transportation's Hazardous Materials Regulations (49 CFR Parts 171 through 180). This requirement does not apply to building materials (such as wood, stone or asphalt) or fuel. Permittees are required to maintain Material Safety Data Sheets (MSDS) sheets for any hazardous materials on site. For material exceeding 1,000 gallons (or equivalent volume) in quantity, the permittee must also identify the proposed routes for entry and egress from the National Forest.

16. Concern about operations which could exceed the operations anticipated in RFD and FEIS or experiencing environmental impacts in excess of that identified in the FEIS.

- The FS decision on lands available for leasing is subject to conditions in order to comply with FS consent to leasing specific lands (36CFR228.102(e)(1).

Actions needed to address the concern:

a. The FS will monitor oil & gas operations under federal Applications for Permit to Drill. If the number of oil & gas wells drilled reaches 90% of the number of wells estimated in the FEIS, then the Forest will withhold consent to new leases pending a review under 36CFR228.102(e)(1).

17. We have noted a record of accidents, lack of implementation of control measures, and improper use of control measures that have resulted in environmental impacts from development of wells using horizontal drilling and high volume hydraulic fracturing.

- This occurs on state administered and federal administered wells. There appears to be an underlying level of violations on 4 to 10 percent of the inspections (or projects) and about 25 percent of these are considered to be serious. (See Part II of this paper)

Actions needed to address the concern:

a. Identify the above measures to reduce potential impacts.
b. Identify the most sensitive areas of the Forest as not suitable for leasing or suitable only with No Surface Occupancy stipulations.
c. Monitoring implementation of these measures will be done by State inspectors, BLM inspectors and Forest Service inspectors.

PART II: A REVIEW OF THE CONCERNS AND RISKS OF IMPROPER IMPLEMENTATION OF MITIGATION MEASURES FOR HORIZONTAL DRILLING AND HYDRAULIC FRACTURING

US FOREST SERVICE
GEORGE WASHINGTON NATIONAL FOREST, VIRGINIA AND WEST VIRGINIA
JULY 20, 2012

Overview: This document was developed to (1) illustrate the issues surrounding potential effects to aquatic resources from horizontal drilling and hydraulic fracturing for natural gas, (2) review mitigation measures that were designed to minimize specific impacts, and (3) use agency inspection data and research to evaluate the risk of improper implementation of mitigation measures and accidents.

1. Issue: Potential impacts to aquatic resources from horizontal drilling and large volume hydraulic fracturing associated with Marcellus shale gas well development on the George Washington National Forest (GWNF). Horizontal drilling in the Marcellus shale involves large volume hydraulic fracturing, which poses a number of risks to aquatic species and habitats. This type of hydraulic fracturing requires about five million gallons of water per well, with 1-3 wells per pad.[1] The water is mixed with sand and chemicals, and is pumped down wells at high pressure to fracture rock and release natural gas. Issues related to water resources and aquatic species and habitat include water withdrawals, surface water and groundwater contamination, and non-point source pollution from ground disturbing activities.

Water Withdrawals

Water Quantity

The impact from large volume water withdrawals varies not only with geographic area, but also with the quantity, quality, and sources of the water used. The removal of large volumes of water could lead to lowering of water tables or dewatering of drinking water aquifers, decreased stream flows, and reduced volumes of water in surface water reservoirs. These activities could impact the availability of water for drinking and other uses in areas where hydraulic fracturing is occurring.[2] Large volume water withdrawals from ground water can also lead to subsidence and/or destabilization of the geology.[2]

While water availability varies across the country, in some regions water used in hydraulic fracturing represents only a small fraction of total water consumption,[3] nonetheless, there are significant concerns about consumptive water use for shale gas development.[4] Furthermore, many of the water uses (such as power generation, and recreation) are not consumptive in the same way as energy extraction since they do not take water out of the system or degrade water quality.[5] A 2006 report to Congress on the Interdependency of Energy and Water points out that nationally, "available surface water supplies have not increased in 20 years, and groundwater tables and supplies are decreasing."[5]

Public concerns regarding the George Washington National Forest Draft Plan Revision not only focused on large volume, high rate water withdrawals from small streams in the headwaters leaving insufficient stream flow for aquatic biota or to maintain stream habitat;[6,7] but also on withdrawals from watersheds that supply drinking water and other downstream agricultural and industrial uses.[8,9]

Water Quality

The lowering of water levels in aquifers may affect water quality by exposing naturally occurring minerals to an oxygen-rich environment; thereby causing chemical changes that may cause salination of the water and other chemical contaminations. In addition, lowered water tables may cause an upwelling of lower quality water from deeper within an aquifer, siltation or cloudiness of the produced water, or stimulate bacterial growth, causing taste and odor problems.[2]

Withdrawals of large quantities of water from surface water resources (e.g., streams) may have significant impacts on the hydrology and hydrodynamics of these resources. Such withdrawals from streams can alter the

flow regime by changing their flow depth, velocity, and temperature.[10] Additionally, removal of significant volumes of water may reduce the dilution effect and increase the concentration of contaminants in surface water resources.[3] Furthermore, it is important to recognize that ground water and surface water are hydraulically connected;[11] any changes in the quantity and quality of the surface water will affect ground water and vice versa.

Surface and Groundwater Contamination

An average well requiring 3 million gallons of water requires the injection of 15,000 to 60,000 gallons of chemical additives.[2] The chemicals used in hydraulic fracturing may include oils, gels, acids, alcohols, and various human-made organic chemicals; many of these chemicals are potentially hazardous to human health and the surrounding environment.[12] In 2010, EPA compiled a list of chemicals that were publicly known to be used in hydraulic fracturing. The chemicals identified, however, do not represent the entire set of chemicals used in hydraulic fracturing activities. EPA also lacks information regarding the frequency, quantity, and concentrations of the chemicals used, which is important when considering the toxic effects of hydraulic fracturing fluid additives.[2]

To this end, the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, two organizations whose missions both revolve around conservation and environmental protection, created a hydraulic fracturing chemical registry website (http://fracfocus.org) to provide the public access to reported chemicals used for hydraulic fracturing within their area. To help users put this information into perspective, the site also provides objective information on hydraulic fracturing, the chemicals used, the purposes they serve, and the means by which groundwater is protected. The chemical data presented on this site has been submitted on a voluntary basis by participating oil and gas companies. An April 13, 2012 web search of WV DEP's database for active gas wells in the Marcellus shale formation in Wetzel County listed 714 unique wells,[13] however, only two wells were included in a FracFocus search of Wetzel County, WV on the same date.[14] Some of the chemical ingredients used in the hydraulic fracturing fluid from these reports are still listed as proprietary.[15] Although the website provides information to the public, it does not give a complete picture of the chemicals that are being used at all wells.

Surface Water

Large hydraulic fracturing operations require extensive quantities of supplies, equipment, water, and vehicles, which could create risks of accidental releases, such as spills or leaks.[16] Spilled, leaked or released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers.[17] The following are examples of surface spills or releases and their causes:

- tank ruptures
  - Release of 13,000 gallons of fracking fluids that led to elevated salinity and conductivity in an unnamed tributary to Sugar Run and a spring caused by a failed storage tank (Penn Township, Lycoming, PA, 2010).[18]
- piping failures
  - Spill of 250 gallons of fracking fluids into an unnamed tributary of Bruch Creek (a high-quality warmwater fishery) because of a broken transmission line that killed fish and aquatic life (Hopewell Township, Washington County, PA, 2010).[19]
  - Spill of 8,000 gallons of fracking fluid into Stevens Creek and a nearby wetland caused by a failed pipe connection (Dimock Township, Susquehanna County, PA, 2009).[20]
- equipment failure
  - Spill of between 4,200 to 6,300 gallons of flowback fluids into an unnamed tributary to Webier Creek (which drains to the Tioga River) because of a failed pump (Armenia Township, Bradford County, PA, 2010).[21]

- surface impoundment failures
  - Discharge of produced waters containing benzene and other hydrocarbons to ground waters and an unnamed tributary to Cascade Canyon because of a tear in a waste pit liner (Garfield, CO, 2010).[22,23]
  - Release of over 1 million gallons of flowback waters into the Parachute Creek drainage because of a ripped waste pit liner (Garfield County, CO, 2008).[24]
  - 550 instances of groundwater contamination caused by failed waste pits (New Mexico, 2003).[25]
- overfills
  - Spill of fracking fluid from an overfilled wastewater pit into an unknown tributary of Drake Run (a high-quality watershed) (Hopewell Township, Washington County, PA, 2010).[26]
- accidents (including vehicle collisions)
  - Vehicle crash involving two tractor trailers, one of which overturned and leaked fracking fluid onto the roadway and an unknown amount into Larry's Creek (Mifflin Township, Salladasburg, PA 2011).[27]
  - Discharge of petroleum-material to Buckeye Run and Buckeye Creek (Doddridge County, WV, 2010).[28]
  - On April 20, 2011 Chesapeake Energy lost control of the Atgas 2H Marcellus Shale well in Bradford County during hydraulic fracturing, over 10,000 gallons of fracturing flow back fluid escaped the well pad and all containment, flowed down a pasture and into an unnamed tributary to Towanda Creek, and Towanda Creek itself. About seven nearby residences were voluntarily evacuated at Chesapeake's suggestion (Bradford County, PA, 2011).[16]
  - On June 3, 2010 operators lost control of the Punxsutawney Hunting Club 36 well. The well is owned by EOG Resources Inc. The company performing the well completion work at the time of the blowout was C.C. Forbes of Washington, Pennsylvania, a division of Forbes Energy of Texas. Well drilling began in January 2010 and hydraulic fracturing operations began in March. Fracturing was completed on May 28th, and the plug placed after fracturing was being removed in preparation of putting the well into commercial production. When the operators lost control, natural gas was released uncontrollably and fracturing fluids in the well were discharged onto the ground and 75 feet into the air for approximately 16 hours (Punxsutawney, PA, 2010). [16]
- drilling and production equipment defects
  - Thousands of gallons of fracking fluids were spilled on farm land and into Towanda Creek (which empties into the Susquehanna River) from a well blowout (LeRoy Township, Bradford County, PA, 2011).[29]
  - Release of benzene and other hydrocarbons into private wells and six springs flowing into Line Creek caused by well blowout (Clark, WY, 2006).[30]
- improper operations
  - Partially treated drilling wastewater containing bromide discharged by Beaver Falls Municipal Authority into Beaver River (Beaver County, PA, 2011).[31]
  - Conclusion by industry representatives and state officials that gas drilling is partly responsible for rising bromide levels in rivers (Monongahela River, PA, 2011).[32]
  - Discharge of flowback fluids into a drainage ditch and then an unnamed tributary of the south branch of Sugar Creek (Troy Township, Bradford County, PA, 2010).[33]
  - Study by Arkansas Department of Environmental Quality (ADEQ) found that waste fluids from gas production have been improperly applied to land farms resulting in discharges to surface waters (Arkansas, 2009).[34]

Groundwater

Advocates of natural gas development often state that the process of hydraulic fracturing has never in its history been tied to the contamination of underground sources of drinking water.[16] Virginia's Department of Mines, Minerals and Energy specifically states that "there have been no documented instances of surface water or groundwater degradation from fracing in Virginia."[35] Yet opponents of hydraulic fracturing can point out several instances in which public water supplies have been adversely affected by drilling, such as Dimock, PA. So, who is correct? The evidence suggests both. There are definitely multiple documented cases of water well contamination linked to gas drilling, but all of them have been linked by the EPA to problems with well drilling (as opposed to hydraulic fracturing), such as casing failures, blowouts, and spills.[12]

EPA found evidence showing that improper well construction or improperly sealed wells may provide subsurface pathways for ground water pollution by allowing contaminant migration to sources of drinking water.[36,37,38,39,40,41] Based on these findings, EPA believes that well mechanical integrity will likely be an important factor in preventing contamination of drinking water resources from hydraulic fracturing activities.[2]

In addition to concerns related to improper well construction and well abandonment processes, there are concerns about the repeated fracturing of a well over its lifetime. Hydraulic fracturing can be repeated as necessary to maintain the flow of gas or hydrocarbons to the well. The near- and long-term effects of repeated pressure treatments on well components (e.g., casing, cement) are not well understood. While EPA recognizes that fracturing or re-fracturing existing wells may pose a risk to drinking water resources, this is not part of their proposed study, because they are unable to identify potential partners for a case study.[2]

Below are examples of groundwater contamination from gas well drilling:

- Poorly constructed wells with defective cement and well casings developed by Cabot Oil and Gas Corporation allowed shallow methane to migrate into water supplies, making 14 water supplies unusable (Dimock Township, Susquehanna County, PA, 2009).[16]
- Study of drinking water samples from wells within 1 km of active drilling sites had 17 times more deep "thermogenic" methane than wells further way (Northeastern PA and Otsego County, NY, 2011).[42]
- The causal relationship between drilling activities and methane in drinking water has also been disputed (Susquehanna County, PA 2011)[81]
- Methane in the drinking water supply for 16 families because of improper well completion (Bradford County, PA, 2010).[43]
- Thermogenic methane in two residential drinking water wells from nearby deep gas drilling (Parker County, TX, 2010).[44]
- Thermogenic methane entering shallow groundwater wells because of improper well completion (Dimock Township, Susquehanna County, PA, 2009).[45,46]
- Methane and ethane in two water supplies from over-pressurized wells and improper well completion (Bradford Township, McKean County, PA, 2009).[47]
- Methane in multiple private drinking water wells and surface waters caused by well casing failure (McNett Township, Lycoming County, PA, 2009).[48]
- Methane in two private drinking water wells likely linked to a recently drilled neighboring gas well (Knox Township, Jefferson County, PA, 2009).[48]
- Study showed temporal trend of increasing thermogenic methane in groundwater coincident with the installation of more gas wells in the area (Garfield County, CO, 2008).[49]
- Methane in drinking water aquifer because of over-pressurized wells and improper well completion (Bainbridge Township, Geauga County, OH, 2008).[50]
- Methane in several private water wells caused by an over-pressurized gas well (Hamlin Township, McKean County, PA, 2007).[48]
- Methane in groundwater caused by over-pressurized wells (Allegheny Forest, PA, 2007).[51]

- Methane in soil near homes caused by recently drilled neighboring gas wells (Millcreek Township, Erie County, PA, 2007).[48]
- Methane in several private water supplies caused when fracking of new well interacted with improperly cased abandoned gas well (Washington County, PA, 2006).[48]

Non-point source pollution from ground disturbing activities

All phases of natural gas well development, from initial land clearing for access roads, equipment staging areas and well pads, to drilling and fracturing operations, production and final reclamation, have the potential to cause water resource impacts during rain and snow melt events if stormwater is not properly managed.[17,52]

Initial land clearing exposes soil to erosion and more rapid runoff. Construction equipment is a potential source of contamination from such things as hydraulic, fuel and lubricating fluids. Equipment and any materials that are spilled, including additive chemicals and fuel, are exposed to rainfall, so that contaminants may be conveyed off-site during rain events if they are not properly contained. Steep access roads, well pads on hill slopes, and well pads constructed by cut-and-fill operations pose particular challenges, especially if an on-site drilling pit is proposed.[17,53]

Each drilling pad occupies 2-6 acres of ground,[1] not including roads and pipeline. The Cumulative Reasonable Foreseeable Development (RFD) for Alternative H for the GW Plan Revision includes 177 wells, 42 miles of roads, and 46 miles of pipeline; which equates to an estimated 672 acres of ground disturbance.[63] Fugitive dust may also be problematic for adjacent waterways.[17] The following are examples of exacerbated erosion and sedimentation:

- During a routine inspection of a well site that was drilled and ready for production, the Department observed erosion and sedimentation violations at the site. The Operator did not implement and maintain BMPs to minimize accelerated erosion and sedimentation in order to protect, maintain, reclaim, and restore water quality and existing and designated uses (Greene County, PA, 2009).[54]
- Sediment discharge to two unnamed tributaries to Wolcott Creek from construction of a road without proper erosion and sedimentation control measures (Athens Township, Bradford County, PA, 2005).[55]
- Runoff from gas well sites was found to contain high concentrations of total suspended solids and heavy metals, rates similar to typical construction activities and urban runoff, respectively (City of Denton, TX, 2008).[56]
- Study of gas development in federal forest found erosion and damage to new and existing roads and ditches from heavy truck traffic, significant damage to trees and vegetation in areas were fracking wastes were land applied, and increased forest fragmentation that altered wildlife movements and could facilitate the introduction of invasive exotic species (Fernow Forest study, WVA, 2011).[57]
- Preliminary study showed significant correlations between gas well density and riparian canopy coverage and indicators of stream health (chemical contaminants and the degradation of macroinvertebrate community structure) and suggested that increasing well density increases the cumulative impacts of extraction (Academy of Natural Sciences study, Susquehanna County, PA, 2011).[58]
- West Virginia Division of Highways notes significant damage to roads from vehicles carrying water, sand, and equipment for local gas recovery activities (Wetzel County, WV, 2011).[59]
- Report of road damage and dust from heavy truck traffic that supports shale gas recovery in area (Marshall County, WV, 2011).[60]
- EPA cites company for filling of a stream and destruction of a waterfall to create a gravel road, and illegal impoundment (Wetzel County, WV, 2010).[61]
- Two major landslides associated with drilling activities caused unstable conditions during wet weather; repairs to well pad will take up to a year (Wetzel and Marshall Counties, WV, 2012).[62]

2. Mitigation Measures: Hydraulic fracturing for oil and gas production wells is typically addressed by state oil and gas boards or equivalent state natural resource agencies. However, EPA retains authority to address many issues related to hydraulic fracturing under its environmental statutes. The major statutes include the Clean Air Act; the Resource Conservation and Recovery Act; the Clean Water Act; the Safe Drinking Water Act; the Comprehensive Environmental Response, Compensation and Liability Act; the Toxic Substances Control

Act; and the National Environmental Policy Act. EPA does not expect to address the efficacy of the regulatory framework as part of their Study on the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources.[2]

In addition to the Department of Mines and Minerals in Virginia, and Office of Oil and Gas in West Virginia, regulatory measures guiding gas development on the GWNF include BLM regulations and FS plan standards. Mitigation measures were developed by the IDT to address each of the potential impacts. These include following Gold Book and API standards and all applicable FS plan standards, BLM regulations, and VA and WV State regulations. To address water withdrawal concerns, water withdrawal for gas development is not allowed on the Forest unless it is demonstrated to result in fewer overall impacts than if water withdrawals were allowed. To address spills and impoundment failures, the plan requires closed loop systems for hydraulic fracturing and the use of a secondary containment system at the drill site. To reduce the potential for groundwater contamination, BLM utilizes strict requirements for casing and cementing of the wells. The plan also contains standards to prevent erosion and sedimentation and to control cuts and fills that could result in unstable conditions. For a complete list of mitigation measures see George Washington Revised Land Management Plan.[63]

A similar approach of developing mitigation around specific concerns was used by New York DEP in their Revised sGEIS for *Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs for large volume hydraulic fracturing.* NYDEP noted a number of widely publicized regulatory violations, non-routine incidents and enforcement cases; and followed with information about the measures currently required in New York or those that the Department proposes to require that are designed to prevent similar problems if high-volume hydraulic fracturing is permitted in the Empire State. NYDEP then provided a lengthy summary of potential impacts and proposed mitigation measures.[17]

Similarly, after conducting a complete review of existing and proposed statutes, legislation, regulation, and policies that regulate or affect Marcellus Shale natural gas development, the Pennsylvania Governor's Marcellus Shale Advisory Commission came up with list of recommendations dealing with infrastructure, public health, safety, and environmental protection, local impact and emergency response, and economic and workforce development.[16]

In addition, the Ground Water Protection Council (GWPC) conducted a study for the U.S. Department of Energy (DOE), Office of Fossil Energy, Oil and Natural Gas Program, and based on an analysis of the requirements specified in state oil and gas regulations, developed key messages and suggested actions.[64] The State Review of Oil and Natural Gas Regulations, Inc. (STRONGER, Inc.) then took this study and developed draft guidelines (2010).[65]

In August 2011, the Secretary of Energy Advisory Board (SEAB) issued a report with recommendations for improving the safety and environmental performance of natural gas hydraulic fracturing from shale formations. They identified four major areas of concern: possible pollution of drinking water, air pollution, community disruption, and cumulative adverse impacts on communities and ecosystems. Recognizing the serious environmental impacts underlying these concerns and the need for them to be prevented, reduced, and where possible, eliminated as soon as possible, the report included 20 recommendations in four key areas: 1) public accessibility to information about gas production, 2) short term and long-term actions to protect air and water quality, 3) systemic approach to development of best operating practices, and 4) research and development to improve safety and environmental performance. These recommendations if implemented are designed to reduce the environmental impacts from shale gas production.[4]

3. The Concern: The concern is that there will still be a risk of accidents, failure of mitigation measures, and failure to comply with mitigation measures; which can lead to environmental impacts and degradation. In their Ninety-Day-Report, the Secretary of Energy Advisory Board recognizes that public concerns extend to accidents and failures associated with poor well construction and operation, surface spills, leaks at pits and impoundments, truck traffic, and the cumulative impacts of air pollution, land disturbance and community disruption.[4]

Additionally, EPA recognizes that during every stage of water use in hydraulic fracturing operations there is potential for issues with contamination of drinking water, including: on-site spills and/or leaks; chemical and wastewater transportation accidents; accidental release to ground water (e.g., well malfunction); improper pit construction, maintenance, and/or closure; and incomplete treatment of wastewater and solid residuals.[2]

In their review, the NYDEP found that "standard stormwater control and other mitigation measures would not fully mitigate the risk of potential significant adverse impacts on water resources from high-volume hydraulic fracturing. Even with such controls in place, the risk of spills and other unplanned events resulting in the discharge of pollutants associated with high-volume hydraulic fracturing operations, even if relatively remote, would have significant consequences" in the unfiltered water supplies of New York City and Syracuse. "In addition, the increased industrial activity associated with well pad development, road construction and other activities associated with high-volume hydraulic fracturing is not consistent with the long-term protection"[17] of the surface drinking water supplies. Accordingly, NYDEP prohibited this this type of development in the New York City and Syracuse water supply watersheds.[17]

Inspection Data

Even with mitigation measures in place, the record shows there will be impacts to aquatic resources from regulation violations and accidents. A review of PA DEP Marcellus well inspection data from January 2000 to January 2012 found that out of 19,650 inspections, almost 10% (1,822) of the PA DEP inspections had violations with the total number of violations being 3,401.[66]

Below are the numbers of violations that occurred by violation code, with an example from inspection comments for that code in parenthesis. The list is not all inclusive, but meant to quantify and illustrate the types of problems that can occur:

- 51 violations 102.11 - Failure to design, implement or maintain BMPs to minimize the potential for accelerated erosion and sedimentation (Mud off pad across township road and into creek)
- 33 violations 102.22 - Failure to achieve permanent stabilization of earth disturbance activity (Site still has erosion issues and is not properly stabilized and 05/10/2011 spill still not cleaned up)
- 444 violations 102.4 - Failure to minimize accelerated erosion, implement E&S plan, maintain E&S controls. Failure to stabilize site until total site restoration under OGA Sec 206(c)(d) (Fill Berms not constructed per plan and do not exhibit E&S BMPs, erosion occurring at Sediment basin, silt sock not installed per plan)
- 53 violations for 105NOPERMIT - Encroachment without Permit or Waiver (unpermitted filling of a wetland or stream crossing)
- 32 violations 206REST - Failure to restore site w/in 9 months of completion of drilling or plugging (No E&S Plan, Well Complete 17 months ago and no restoration/report, waste lying around site)
- 16 violations 207B - Failure to case and cement to prevent migrations into fresh groundwater (Gas migrating to surface through cement on backside of 13 3/8" water string. Operator in process of mitigating problem)
- 2 violations 208A - Failure to restore a water supply affected by pollution or diminution (CW-complaint investigation ultimately determined Stang 1 Well had impacted quantity and quality of private drinking water well within 1000 feet of gas well, CO&A negotiated for Stone Energy to replace or restore potable drinking water to Clinton Property)
- 6 violations 209BOP - Inadequate or improperly installed BOP, other safety devices, or no certified BOP operator (PHC 36H 033-26872 - Failure of blow out prevention equipment, uncontrolled discharge of natural gas and flowback fluids, well vented for approx 18 hours before it was shut in.)
- 60 violations 301CSL - Stream discharge of IW, includes drill cuttings, oil, brine and/or silt (Investigated 2,400 gallon mud spill to unnamed trib to Ten Mile Creek through a seasonal stream. Violations noted)
- 40 violations 301UNPMTIW - Industrial waste was discharged without permit (Encroachment without permit, frac out released bore gel to stream, petroleum product spilled to ground with potential to enter stream)
- 19 violations 307CSL - Discharge of industrial waste to waters of Commonwealth without a permit (operator discharging flowback to site. Less than 5 gal observed being discharged to ground. No containment in place)

- 10 violations 401CAUSEPOLL - Polluting substance(s) allowed to discharge into Waters of the Commonwealth (Water transfer line - released full volume directly into 2 streams)
- 258 violations 401CSL - Discharge of pollutional material to waters of Commonwealth (erosion from access road flowing heavily into stream)
- 130 violations 402CSL - Failure to adopt pollution prevention measures required or prescribed by DEP by handling materials that create a danger of pollution (Drilling Cutting/Cement mix has spilled from the container and onto the ground. Residual waste has sprayed off containment and off site. Containment around tanks is insufficient)
- 15 violations 402CSL B - Failure to meet requirements of permit, rules and regulations, or order of DEP. (ex. Discharge of ethylene glycol to pad and flowback to drainage ditch)
- 73 violations 402POTNLPOLL - There is a potential for polluting substance(s) reaching Waters of the Commonwealth and may require a permit.(ex. Violations noted at this site were due to a 1,500 gallon spill of drilling mud being observed on the surface of the)
- 41 violations 51017 - Administrative Code-General (Accelerated erosion, pollutional substances on ground and not in proper containment, waste on ground) (No well tag, oil spill on ground)
- 402 violations 601.101 - O&G Act 223-General. Used only when a specific O&G Act code cannot be used (78.86 defective casing or cementing, 78.81(a)(2) failure to prevent migration of gas or other fluids into sources of fresh groundwater, O&G Act 601.201(f) failure to submit written notice of intent to plug well or amend plat. MBC 5/20/09) 6000 gallons of frac flowback off site into wetland. Wetland discharge into unnamed tributary of Webier Creek (CWF).
- 155 violations 691.1 - Clean Streams Law-General. Used only when a specific CLS code cannot be used (DCNR complaint rec'vd, insp documented CSL 401 & 307 and SWMA 301 viols, surfactant discharge to ground surface exiting fractures in rock formation and leaving site at approx rate of 180 gal/min, entered Pine Creek, applicable wells shut down, follow-up actions needed.)
- 2 violations 691.401WPD - Failure to prevent sediment or other pollutant discharge into waters of the Commonwealth. (Crews were on-site at the time of the inspection. Site ID and E&S plan located. Violations noted: 1- Failure to minimize accelerated erosion and sedimentation. 2- Inadequate E&S plan. 3- Discharge of Industrial Waste to the Waters of the Commonwealth.)
- 11 violations 691.402 & 691.402WPP - Site conditions present a potential for pollution to waters of the Commonwealth (Following up on complaint, truck accident resulting in release of diesel fuel in January 2010 not reported to DEP, found other violations existing on well pad, truck accident release was referred to ECP.) (Encroachment without permit, frac out released bore gel to stream, petroleum product spilled to ground with potential to enter stream)
- 94 violations 78.54 - Failure to properly control or dispose of industrial or residual waste to prevent pollution of the waters of the Commonwealth. (Bubbling observed in cellar. Drilling complete. DEP will investigate bubbling further after cellar cleaned out. Excessive drill mud/cuttings on plastic and has been tracked off containment onto pad and up access road. Tears in plastic observed. Operator to get crews to clean up site ASAP and notify DEP upon completion for follow up inspection.)
- 15 violations 78.55 - No Control and Disposal/PPC plan or failure to implement PPC plan (operator had 30 gallon diesel fuel spill on ground and also found diesel fuel in drill pit also. ALSO 3rd time operator was ask for ppc plan and is NOT on location !!!!!)
- 143 violations 78.56(1) - Pit and tanks not constructed with sufficient capacity to contain pollutional substances. (Discharge of ethylene glycol to pad and flowback to drainage ditch)
- 188 violations 78.56(2) & 78.56FRBRD - Failure to maintain 2 ' of freeboard in an impoundment. (Pit has hole in liner and perimeter fence is down, lacking 2 feet freeboard, drilling mud spill on ground, Accelerated erosion due to insufficient site stabilization)
- 38 violations 78.56(3) - Impoundment not structurally sound, impermeable, 3rd party protected. (>5 acres disturbance and no ESCGP, accelerated erosion, pit has holes in liner, waste lying around site)
- 90 violations 78.56LINER - Improperly lined pit (CSL 401 black fluid discharge to surface and waters in area of Hibbard 2H & 4H well pad, 78.56(a)(1) tears in liner.)
- 103 violations 78.56PITCNST - Impoundment not structurally sound, impermeable, 3rd party protected, greater than 20" of seasonal high ground water table. (Flowback spill extends roughly 800 to 1,000 feet from well site. Large swath of dead vegetation.)
- 31 violations 78.57 - Failure to post pit approval number (§ 78.57(a) violation. Production fluids were allowed to escape the production pit onto the ground and leave the work site.)

- 18 violations 78.57C2 & 78.57PITAPPR - Failure to construct properly plug, frac, brine pits (Production tank leak, 400 brls approx.)
- 12 violations 78.60 & 78.60B - Tophole water discharged improperly ("Discharge to stream Channel. Violation of 78.60(b)(5))
- 16 violations 78.62 & 78.64- Improper encapsulation of waste and oil tank (Multiple viols for 3 main issues: (1) Above ground pit -- Improperly lined pit, not structurally sound, drill cuttings on the ground around pit. (2) Diesel fuel spill to the ground. (3) Dusting/land application of cuttings without approval.)
- 27 violations 78.65(1) - Rat hole not filled (Rat hole open and waste all over site)
- 12 violations 78.65(3) - Failure to submit or submitting an inadequate well site restoration report within 60 days of restoration of the well site & 78.66A - Failure to report release of substance threatening or causing pollution (No E&S Plan, Well Complete 17 months ago and no restoration/report, waste lying around site)
- 6 violations 78.74 - Hazardous well venting (PHC 36H 033-26872 - Failure of blow out prevention equipment, uncontrolled discharge of natural gas and flowback fluids, well vented for approx 18 hours before it was shut in.)
- 53 violations 78.83GRNDWTR - Improper casing to protect fresh groundwater (Insufficient casing & Incorrect setting depth)
- 20 violations 78.84 - Insufficient casing strength, thickness, and installation equipment & 78.85 - Inadequate, insufficient, and/or improperly installed cement (gas in annular space)
- 127 violations 78.86 - Failure to report defective, insufficient, or improperly cemented casing w/in 24 hrs or submit plan to correct w/in 30 days (Bubbling between 9 5/8 and 13 3/8 annuli. 62% combustible gas reading utilizing MSA Model 60 meter. Uncontrolled release of gas. Isotopic obtained. No well tag on wellhead. 5 wells on location.)
- 72 violations 91.33A & 91.33B & 91.33POLLINC- Failure to notify DEP of pollution incident. No phone call made forthwith (48bbls of drilling mud released to well pad. No mud left site or into streams. 30hr time lapse between release and report. Report from Patterson Drilling not operator. Cert Mail NOV sent 10/05/09. Inspection report related to Mark Barbier 10/01/2009 inspection.)
- 26 violations 91.34A - Failure to take all necessary measures to prevent spill. Inadequate diking, potential pollution (Violations noted at this site were due to a 1,500 gallon spill of drilling mud being observed on the surface of the ground outside of the containment area and the site PPC plan was not available for review upon request.)
- 27 violations CSL402POTPOL - There is a potential for polluting substance(s) reaching Waters of the Commonwealth and may require a permit (KC-report rec'vd of fluid spraying out of vents on holding tanks, water line from well froze, during thaw it released pressure and forced produced fluid (brine) out of vents.)

It is recognized that the majority of the wells in PA are neither on public land, nor subject to federal government oversight by the BLM or FS regulators. It is expected that wells on GWNF would be under more strict guidelines and stringent inspections. Accordingly, the mitigation measures identified by the GWNF would incorporate standards and best practices for hydraulic fracturing identified by the American Petroleum Institute as conditions of approval for the APD;[67] utilize the standard practices (including casing and cementing requirements) for drilling operations in the Gold Book[68] and Onshore Oil & Gas Orders No. 1[69] & No. 2[70]; and monitoring implementation of these measures by State inspectors, BLM inspectors and Forest Service inspectors.[63]

However, recent review of drilling on public lands by the Democratic staff of the House Natural Resource Committee found many safety and drilling violations that have and could harm the environment and public health.[71] There were a total of 2,025 safety and drilling violations that were issued by BLM to 335 companies drilling in seventeen states between February 1998 and February 2011. Of these, 27 percent were classified by Committee staff as a major environmental or safety violation, 20 percent as a minor safety violation and 53 percent as a minor drilling or operational violation. The review goes on to report that only six percent of violations resulted in fines, the fines were inconsistently applied, and they were so low as to be inconsequential to many operators. Since the strongest tool against companies that fail to comply with the rules and regulations of drilling on federal lands is to levy monetary fines, these types of “penalties and the

inconsistent way in which they are levied do little to ensure accountability and protection of the surface and subsurface environment."[71]

Furthermore, although Onshore Order No. 1, which contains the information an operator must submit to the BLM for the approval of proposed gas exploration and development on federal lands, was amended in 2007, Onshore Order No. 2, which sets the minimal requirements for well design, construction and well control, including minimum casing and cementing requirements, has not been updated since 1988. It reflects neither the significant technological advances of hydraulic fracturing and associated technologies nor the tremendous growth in its use.[71] BLM makes it a priority to witness the required casing and cementing procedures as planned under Onshore Order No. 2; but the House Natural Resource Committee found that these procedures are frequently not followed and operators regularly fail to notify BLM as to when they will occur, resulting in casing and cementing activities that are often performed without a BLM witness present to ensure it happens in a manner that would protect water sources.[71]

Recently, the Shale Resources and Society Institute at the State University of New York at Buffalo released a report, *Environmental Impacts During Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies.*[72] The report uses the violations previously discussed for the State of Pennsylvania, but it examines them in greater detail. In 3½ years, from January 2008 through August 2011, the State issued 2,988 notices of violation. Of these, 1,144 were for environmental violations (as opposed to administrative or preventive violations) and these violations addressed 854 unique environmental events. Twenty-five of these events (or 3 percent) were classified as major environmental events, defined as major site restoration failures, serious contamination of local water supplies, major land spills, blowouts or venting, and gas migration; of these 25 events, six cases did not have their environmental impacts completely mitigated. The incidence of all environmental events declined from 53 percent of all of the wells drilled in 2008 to 21 percent of the wells drilled in 2011. At this rate, one in five wells would be expected to have an environmental event. The incidence of environmental violations was similarly reduced from 58 percent to 27 percent; one in four wells would have an environmental violation. The report suggests that "while a 26.5% rate of environmental violations appears high, it is important to note that most of these violations are not major." For this report, violations pertaining to erosion and sedimentation are considered minor. The reduction in environmental violations was attributed to improvement by the industry and oversight by the regulators.

The study goes on to examine the twenty-five major environmental events in relation to the guidelines proposed in the Supplemental Generic Environmental Impact Statement in New York.[72] The authors indicate that each of the underlying causes associated with the events could have been either entirely avoided or mitigated under the proposed New York guidelines. However, the final conclusion is that the majority of the polluting environmental events were due to operator error, negligence, or a failure to follow proper procedures when drilling, and that surface activity, rather than the drilling or development process itself, remains the greatest ongoing risk.

Accident Data

Even if all regulations are followed and inspections are clean, because of the extensive quantities of supplies, equipment, water, and vehicles there is still a risk of accidental releases of fluid or chemicals from spills or leaks.[16] In addition, because of the level of ground disturbance associated with multi-well pads, roads, impoundments, and pipelines there is still a risk of failure of erosion control measures to adequately contain sediment or other contaminants.[17]

A good example of the accident potential is from a single well drilled on Forest Service land in the Fernow Experimental Forest, West Virginia. The results of FS researchers monitoring and observing the effects of well development led to two obvious points: "that some effects can be predicted and mitigated through cooperation between landowner and energy developer, and that unexpected impacts will occur. These unexpected impacts may be most problematic."[57] Under the "Expected or Predicted Impact" section of the report, silt fences were undermined and overtopped repeatedly, routing concentrated flow and associated sediment to a sinkhole; three caves were drilled through; and heavy vehicle traffic when the roads were wet caused drainage ditches to fill and collapse and the road surface to erode.

The "Unexpected Impacts" section included loss of control of the drill bore and subsequent release of materials that damaged vegetation adjacent to the well and drill pad, and extensive permanent damage to vegetation caused by land applied drill pit fluids that had a higher actual loading of chloride than the permitted concentration. The "Other Unexpected Impacts" section of the report included effects from heavier-than-predicted truck use leading to road damage (both more trucks on the road, and heavier truck weight); runoff and erosion that was not repaired as soon as it occurred or was pointed out; changes in wetland and stream crossings from the pre-approved directional boring to the energy company's preferred method of dry trenching; an excavator break-down within the stream channel while dry trenching; and damage from a truck carrying pipeline that ran off the road in the Biological Control Area (used as reference for silvicultural research) and from the bulldozer used to push the truck back on the road. Good coordination and cooperation minimized the mostly physical effects from expected impacts, while the unexpected impacts were less likely to be mitigated successfully; [57] this points out the need for good communication among all parties for the duration of the drilling operation.

In an attempt to quantify accidents, the WV DEP Office of Oil and Gas database was queried for oil and gas spills between January 2000 and January 2012. Although, the information is not specific to drilling in Marcellus shale, the returned data shows there were 463 oil and gas spills reported between January 2000 and June 2009.[73] This would average about 54 spills per year, and does not include inspection violations, of which there were 2,102 between July 13, 2000 and December 21, 2011. [74] Examples of comments recorded from the reported spills include:

- Oil line running under county road leaked 40 gallons of crude oil into creek (Calhoun County, WV. March 14, 2008)
- Spilled 7.5 barrels of drilling fluid into Paddy Run while drilling well. (Gilmer County, WV. July 14, 2008)
- Drilling spill released 2,500 gallons saltwater/brine, some of which reached Fink Creek (Lewis County, WV. August 21, 2000)
- Set fire to oil tank- oil running in stream (Roane County, WV. May 21, 2008)

Resource on the GW:

The U.S. Geological Survey (USGS) indicates that the Marcellus play for Virginia is on the outer periphery of the major structural body of the shale.[35] As a result, VDMME feels the concerns regarding conditions in other states are less likely to exist in the Commonwealth. Utilized in Southwest Virginia since the early to mid-1950s, much of the hydraulic fracturing process in Virginia uses a pressurized nitrogen-based foam.[35] In their 2011 comments on the Draft GW Plan Revision, VDMME suggested that the nitrogen-based fluids could be used to fracture horizontal wells in Virginia's Marcellus shale, thereby using much less water, and minimizing the potential withdrawal and contaminated flowback issue.[75] However, slick water (water-based) stimulation has been shown to be more effective than nitrogen fracturing in Marcellus shale,[75] and the VDMME now states that water-based hydraulic fracturing fluids would most likely be used in the Virginia Marcellus formation, but at less volume than reported in neighboring states due to the thinner, less extensive formation characteristics. In addition, it is important to note that a well drilled in the Marcellus shale may have to be hydraulic fractured several times over the course of its life to keep the gas flowing, and that each hydraulic fracturing operation may require more water than the previous one,[77] but it is not known how much or how often this would have to be done in Virginia. Clearly, there are still unknowns about the condition of the Marcellus shale and its gas resource on the GWNF.

In a 2011 report about the undiscovered gas resources of the Devonian Marcellus shale[78], the USGS identified three Marcellus shale assessment units. Lands on the GWNF lie within the Folded Marcellus Assessment Unit. It is estimated that this assessment unit contains less than 1 percent of the total undiscovered gas resources in the three assessment units.

4. Implications for Aquatic Resources for Alternative H:

As previously stated in the Mitigation section of this report, measures could be incorporated into the Forest Plan to mitigate or reduce many of the impacts that would be expected in the development of Marcellus shale

gas. These include standard measures used by the BLM, required measures from the State of West Virginia and Commonwealth of Virginia, and additional measures developed for the forest plan. While these measures are designed to limit environmental effects, it is recognized that accidents and unintended actions will occur. To address these factors Alternative H has identified areas to further minimize risk of impacts. This alternative makes public water supply watersheds unavailable for leasing and makes the following areas available only with No Surface Occupancy: Special Biological Areas, Shenandoah Crest, Key Natural Heritage Community Areas, Indiana Bat Secondary Protection Areas, Special Geologic Areas, and the areas above 3,000 feet in elevation on Shenandoah Mountain south of Highway 250 (about 141,000 acres). In Alternative H, the lands identified as available for leasing would be further constrained to only address those areas where the potential for gas resources is high. Thus the Lee Ranger District, Pedlar Ranger District and the Warm Springs and Back Creek Mountains of the Warm Springs Ranger District would not be made available for leasing.

This would leave about 330,000 acres with Controlled Surface Use, Standard, or Timing stipulations in Alterantive H. A GIS analysis was done using these 330,000 acres, plus the 141,000 with leasing but No Surface Occupancy, and an additional 39,000 acres of private mineral rights within Marcellus shale, for a total of about 510,000 acres which could be leased for high volume horizontal drilling to extract natural gas from Marcellus shale, to determine the aquatic resources within that area. The Forest's GIS "streams" layer was used to calculate perennial and intermittent stream miles, and riparian corridor acres around streams,[78] while the shapefiles developed for the Aquatic Ecological Sustainability Analysis[79] were used to calculate miles of potential brook trout habitat and aquatic TESLR habitat, as well as acres of waterbodies and wetlands within the potentially leasable, Marcellus shale play on National Forest.

- 413 miles perennial streams
- 1,168 miles intermittent streams
- 26,843 acres riparian corridor around perennial and intermittent streams
- 745 miles potential Threatened, Endangered, Sensitive, Locally Rare (TESLR) species habitat
- 514 miles wild brook trout habitat
- 2,771 acres of waterbodies and wetlands

Each drilling pad occupies 2-6 acres of ground, not including roads and pipeline. The Cumulative Reasonable Foreseeable Development (RFD) for Alternative H for the GW Plan Revision includes 177 wells, 42 miles of roads, and 46 miles of pipeline; which equates to an estimated 672 acres of ground disturbance.[63] With that level of development within the mountainous terrain of the GWNF, it is certain that there would be stream and wetland crossings by roads and pipelines, including wild brook trout and TESLR habitat.

The application of forestwide standards and resource protection measures are designed to limit the extent and duration of adverse environmental effects. The allocation of lands to management prescriptions, the decisions on lands administratively available for leasing, and the decisions on leasing stipulations (like No Surface Occupancy) could limit the exposure of the most sensitive resources to the risk of adverse environmental impacts. The record of declining violations in Pennsylvania is encouraging and many state and federal agencies are developing improved regulations to respond to past incidents. However, the record from drilling in other states indicates that there will be accidents, improper implementation of control measures and unintended actions that result in impacts to aquatic resources.

In addition to accidents, the mountainous terrain results in the potential for increased erosion and sedimentation from soil disturbances associated with road and well pad construction, and associated facilities and pipelines. These effects can be long-term as they involve land use conversion from forest to non-forest with a loss of soil productivity and natural landform. There would also be the potential for increased runoff on compacted soils which could cause changes to streamflow volumes and timing of flows. Some level of sediment from roads would reach streams and wetlands and could impact the physical characteristics and biological integrity of water resources.[53] See the GW Plan Revision EIS for a more complete discussion on potential effects to water resources.[1]

Some level of adverse effects to the above resources would likely be unavoidable and it is important to note actual effects would not occur until project-level decisions are implemented. If we assume that newly

developed regulations and control measures would cut violations in half, we could still expect five to ten percent of wells to have problems. Of these from three to twenty-five percent of the wells could cause major impacts. This would translate to about one to two wells. While this is a small amount, the previously identified extent of the sensitive aquatic resources could still result in impacts to miles of streams serving sensitive aquatic resources. In addition, it assumes a level of compliance with regulations and lack of accidents that has not yet been demonstrated. This level of impact generates concerns that would require the continued search for improved control measures and greater oversight to reduce unintended actions during implementation.

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