FINAL DRAFT

Assessment of Risks from Unconventional Gas Well Development in the Marcellus Shale of Western Maryland

Prepared by:

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This comprehensive risk assessment for unconventional gas well development in the Marcellus Shale is the product of a team of devoted scientists and engineers from the Maryland Department of Environment (MDE) and the Maryland Department of Natural Resources (DNR) who volunteered to take on this project in addition to their normal duties. This effort is led by Matthew Rowe, Deputy Director of the Science Services Administration, MDE. The other team members are: from MDE - Farah Abi-Akar, John Backus, Timothy Fox, Anna Kasko, Jed Miller, M.D., Leonard Schugam, and Angel Valdez; and from DNR - Pamela Bush. The assistance of other staff members from both agencies was invaluable and appreciated. We would like to extend a special thank you to Brigid Kenney, Senior Policy Advisor with MDE's Office of the Secretary and to Christine Conn, Director of the Integrated Policy and Review Unit at DNR for their guidance and direction. We appreciate the assistance of Shareda Holifield of MDE for editing the References. We are especially grateful to Charles Yoe, Ph.D., of Notre Dame of Maryland University who gave a presentation on risk assessment to the Advisory Commission and generously provided advice on structuring the risk assessment.

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Executive Summary

On June 6, 2011, Governor Martin O'Malley signed an Executive Order establishing the Marcellus Shale Safe Drilling Initiative. This initiative will assist State policymakers and regulators in determining whether and how gas production from the Marcellus shale in Maryland can be accomplished without unacceptable risks to public health, safety, the environment and natural resources. The Order requires the Maryland Department of the Environment (MDE) and the Department of Natural Resources (DNR), in consultation with an Advisory Commission made up of a broad array of stakeholders, to undertake studies of natural gas drilling in the Marcellus Shale of Western Maryland.

In January 2014, technical staff from the Departments of Environment and Natural Resources convened to perform a comprehensive risk assessment for unconventional gas well development (UGWD) in the Marcellus Shale. Since the science surrounding UGWD is still emerging, there are still many unknowns regarding public health and environmental risks. As a result of uncertainty, this risk assessment is a qualitative evaluation that assigns risks into fairly broad categories and, where necessary, uses professional judgment to rank risks.

Two risk factors, the probability of a risk occurring and its human and ecological consequences, are used to rank risks as overall low, medium, high or having insufficient data to determine risk. The risk assessment process entails first identifying the different phases of UGWD, then identifying human and ecological risks in each phase, grouping these risks into like categories, convening a technical team to evaluate each risk group using current scientific literature, evaluating and applying Maryland's existing regulations and proposed best management practices (BMPs) for effectiveness in mitigating risk, and finally developing an overall qualitative risk assessment assuming the BMPs are in place. Each team evaluated risks using consistent assumptions and evaluations of BMP effectiveness.

Eight categories of risk were evaluated, including: air emissions; roads and traffic; drilling fluids and cutting spills on the well pad; groundwater and surface water contamination risks during transport of fracturing additives and fluids; water contamination risks from well construction and formations; risks from water withdrawal for UGWD; waste disposal risks; and, noise and visual risks. A separate analysis by the Department of Natural resources on forest fragmentation risks associated with gas gathering lines is also discussed. Risks were evaluated during five phases of UGWD: site identification and preparation; drilling; hydraulic fracturing/completion; production; and well abandonment/reclamation. Risks were considered on an individual well pad and/or cumulative basis, as appropriate. Two development scenarios were used to assess cumulative risks, a 25% extraction scenario of 150 total wells and a 75% extraction scenario of 450 total wells. Overall risk assessment findings generally did not differ between the two development scenarios for several reasons. First, for many risks (e.g., spills, well failures, noise, water withdrawals, etc.), increases in the number of wells drilled either did not change the probability or consequence enough to change the overall risk ranking. For example, a low probability and a minor consequence has the same overall risk ranking (i.e., low) as a medium probability and a minor consequence or a low probability and moderate consequence. This results from relatively broad categories for assigning overall risk due to the qualitative nature of the assessment. Second, there was not enough information to numerically quantify risks. Where there was sufficient information to provide numerical estimates of risk (e.g., the rate of accidents associated with increases in well drilling) it was a flat rate and independent of the number of wells drilled. This, and the lack of location-specific information on the actual distribution of wells and well pads, created difficulty in differentiating risk between the two development scenarios.

A general summary of the risk findings are presented in the table below, with additional discussion following.

Risk Category	Risk Summary
Air emissions	Moderate to high risk during hydraulic fracturing with more data needed to evaluate vehicle emissions
Roads and traffic	Some overall moderate to high risks for accidents/injury and road damage
Drilling fluids and cutting spills on the well pad	Generally low risk
Groundwater and surface water contamination risks during transport of fracturing additives and fluids	Generally low risk
Water contamination risks from well construction and formations	Generally low with some moderate risk for methane contamination depending on setbacks
Risks from water withdrawal for UGWD	Generally low risk with potential for moderate during low flow conditions
Waste disposal risks	Generally low risk
Noise and visual risks	Generally low, though moderate to high for compressor and traffic noise, respectively
Forest fragmentation from gathering lines	Moderate to high risk

Looking across the risk assessments of air pollution for each phase, there are several general conclusions regarding risks. First, and with the exception of the seismic assessment phase, there is a high probability of air emissions during all UGWD phases even with BMPs in place. Second, most of these high probability emissions result from multiple, oftentimes overlapping, combustion sources that for several sources (mobile sources, hydraulic fracturing pumps, and compressor emissions) have insufficient data or modeling information to reasonably determine consequences. Furthermore, some of the elevated air emission risks and the inability to estimate others result from uncertainty about which specific control technologies would be employed. Air emissions risks associated with the hydraulic fracturing phase were also ranked higher under the 75% extraction scenario.

Congestion, delays, accidents and road damage caused by the nearly 10,000 one-way truck trips required for the development of a single well are associated with specific risks ranging across the spectrum of low to high. These estimates rely on data from other states with different intensity and pace of oil and gas development and could not be scaled precisely to Maryland. Road damage is inevitable and necessitates the development of road maintenance agreements prior to initiating UGWD. Plans can be developed to manage traffic flow so that it does not impede important community events and gives citizens more predictability for planning their own transportation needs.

One of the greatest concerns regarding UGWD is the contamination of water supplies, both ground and surface waters, which may provide sources of drinking water or support ecologically valuable and sensitive aquatic communities. Risks associated with water contamination were rated most commonly as low, and in some cases, moderate, depending on the sensitivity of the receptor. Practices that manage these risks include 1) preventing accidents and spills by managing traffic flow and ensuring a nearly spill-proof pad design, 2) siting the pad far away from sensitive areas, underground hazards, geologic pathways and drinking water sources, 3) requiring stringent casing and cementing standards followed by integrity tests and extensive monitoring to ensure the safest and most leak-proof wells are being developed, and 4) strict standards for transporting and disposing of waste.

Risks to drinking water supplies from water withdrawals were considered low since Maryland's water use regulations and permitting process are sufficiently protective. However, an elevated risk to aquatic life is possible if large water withdrawals occur over short time periods in water bodies already stressed by drought-, heat- or low flow-conditions.

Risks associated with contamination from improper disposal of drilling wastes were rated low. Maryland has a robust regulatory program for managing waste which requires plans that address waste handling, treatment and disposal. This program also requires waste materials to be tested for contaminants and disposed of in accordance with law. Permits will be issued for each well pad to meet these requirements.

Assuming that best practices are followed, only one risk ranks high for noise and visual impact: noise from the truck traffic associated with transporting the materials for hydraulic fracturing to the well pad. Regardless of the final number of well pads in Maryland, noise and visual impacts are expected to be localized and limited in duration for each site. The probability of impacts of noise due to truck and equipment traffic is high and will necessarily be more significant if more pads are developed concurrently and in close proximity.

The Comprehensive Gas Development Plan (CGDP) and associated location restrictions and setbacks will be instrumental in reducing the extent of forested landscape fragmentation and detrimental impacts to terrestrial and aquatic resources. However, the CGDP will not reduce these risks to low and may not have a strong influence on the siting of the gas pipelines (gathering lines) that run from the well pad to larger pipelines because the locations of the gathering lines is determined by agreements between private parties, and no governmental approval is needed for the locations of gathering lines.

Risks are inherent in any type of mineral extraction, industrial and construction activity. Across the life-cycle of the well, from initial site identification to well abandonment and reclamation, UGWD encompasses a broad range of these activities. Maryland draws from its robust stormwater management, soil erosion and control, and water appropriations programs and examines the effectiveness of proposed best management practices for revising its existing gas and oil development regulations. Together, these existing and proposed practices serve to reduce many risks to Western Maryland's citizens, economy and its high quality water, air and natural resources. Where unacceptable risks still remain despite current regulations and proposed BMPs, the Departments will consider additional practices to reduce risks.

Risk Assessments

Introduction

On June 6, 2011, Governor Martin O'Malley signed an Executive Order establishing the Marcellus Shale Safe Drilling Initiative. The Initiative will assist State policymakers and regulators in determining whether and how gas production from the Marcellus shale in Maryland can be accomplished without unacceptable risks of adverse impacts to public health, safety, the environment and natural resources. The Initiative is jointly administered by the Maryland Department of the Environment (MDE) and the Maryland Department of Natural Resources (DNR). A key purpose of the Initiative is for MDE and DNR, in consultation with a multi-stakeholder Advisory Commission, to conduct a study that examines a range of considerations related to natural gas exploration and production in the Marcellus Shale. Some Advisory Commission members and public participants suggested that a formal risk assessment for Marcellus Shale gas development would add value to the work performed under this Initiative.

In September 2013, Advisory Commission staff prepared a risk assessment (RA) work plan that identified a set of risks and was endorsed the Advisory Commission. In January 2014, the Departments convened a technical committee to perform the RA. The technical committee then formed eight focused risk teams composed of subject matter experts in public and environmental health and natural resource management to evaluate groups of similar risks identified in the Advisory Commission's work plan. Additional risks that were not identified in the work plan but that came to light during risk team evaluations were also considered.

This document describes the RA development and presents its findings. Specifically, it discusses the following: the purpose and scope of the RA; the methodology which includes the assumptions and development scenarios used to develop the RA; and an overview of risks encountered during each phase of unconventional gas well development (UGWD). The detailed team risk assessments that form the basis for the summary assessment are included as appendices.

Purpose and Scope

The purpose of this RA is to provide a comprehensive risk evaluation for UGWD in the Marcellus Shale in Western Maryland. Specifically, risks are evaluated through a qualitative assessment of probability and consequence to achieve an overall risk ranking. This RA does not seek to determine a single aggregate risk evaluation for UGWD in Maryland. The RA findings are intended for consideration by the State of Maryland and the Marcellus Shale Advisory Commission to determine if UGWD can be conducted safely in Maryland with current proposed BMPs.

This RA considers two general points of reference - human/community and ecological receptors - which could be impacted either directly or indirectly by UGWD. Human/community receptors include impacts to human health, welfare, and quality of life; ecological receptors include impacts to aquatic organisms, sensitive areas, and forest or farm fragmentation. The RA does not consider risks to workers on site or in transit to or from sites where UGWD-related activities are being performed. Additionally, the RA does not consider risks related to downstream infrastructure and processing (such as intrastate or interstate gas lines, downstream processing plants, and liquefaction plants) or risks related to broader national energy policies that affect climate change.

Methodology

This section describes the methodology and general sequencing used by the Departments to develop the RA.

Work plan and literature review

The Departments initially reviewed the September 2013 work plan drafted by Advisory Commission staff to determine the scope of the RA and the key risks to be considered. The Departments then reviewed risk assessments by Ricardo AEA (Draft Issue 3a, 2014) and King (2012) in order to fully understand the phases of the UGWD process. This review also included the life cycle phase analysis from Eshleman and Elmore's *Recommended Best Management Practices for Marcellus Shale Gas Development in Maryland* (2013). Each of these sources was used to determine the UGWD phases evaluated in Section III which were used to conduct the Departments' RA.

Identification of risks for evaluation

The Departments, in consultation with the Advisory Commission, accepted the 41 risks selected from the September 2013 RA work plan based on a report from Resources for the Future entitled *Pathways to Dialogue: What the Experts Say about the Environmental Risks of Shale Gas Development* (2013). This list of 41 risks was then subsequently expanded based on further Advisory Commission input and included eight additional risks associated with accidents. These risks were then grouped into the following eight categories:

1. Air emissions

2. Roads and traffic
3. Drilling fluids and cutting spills on the well pad
4. Groundwater and surface water contamination risks during transport of fracturing additives and Fluids
5. Water contamination risks form well construction and formations
6. Risks from water withdrawal for UGWD
7. Waste disposal risks
8. Noise and visual risks

Eight technical teams consisting of representatives from the Departments of Environment and Natural Resources were then convened to develop risk assessments for each category of risk listed above. A separate analysis by the Department of Natural resources on forest fragmentation risks associated with gas gathering lines was also performed.

Literature and other information sources

The eight technical teams reviewed current scientific literature and other available information to evaluate risks and potential impacts to receptors from UGWD. Each team was responsible for evaluating the risks assigned to their category as well as any additional risks that were identified through team literature and information reviews.

The Departments used information from a range of sources to develop the RA. In addition to the Ricardo AEA (2013) and King (2012) reports discussed above, the New York State *Revised Draft Supplemental Generic Environmental Impact Statement* also served as a primary reference. Additional literature and information sources were used to inform development of the individual risk team assessments that form the basis for the summary assessment. Studies that were released during RA development may not have been reviewed due to their timing relative to issuance of this report. It was also clear during literature reviews that many additional studies related to UGWD risks are already planned or underway and will be important for reevaluating risks in any future assessments.

The integrity and credibility of all sources was considered during RA development. Peer-reviewed original papers published in established scientific journals were considered to be generally credible. Reports from federal, state, or local government agencies were also considered to be generally credible.

Consideration of best management practices

After scientific literature review, key risks to receptors were identified and then each team evaluated Maryland's proposed and existing BMPs, including laws, regulations and permits, to determine effectiveness in mitigating risks. The following guidelines were used to evaluate BMP effectiveness in mitigating risks to human and ecological receptors:

- BMPs that require implementation of best available control technology (BAT) that is prescriptive and have proven efficiencies at the start of operation are expected to mitigate risks to a greater degree than BMPs that require plans, time limitations to activities, reporting requirements, or general guidelines.
- BMPs that require implementation of a specific BAT should be distinguished from BMPs that provide flexibility for BAT implementation, as the latter is expected to result in site-specific efficiencies that may be difficult to verify and enforce.
- The availability, or lack-thereof, of literature and data validating BMP effectiveness are important considerations in evaluating risk .
- BMPs that require documented plans are generally expected to identify measures that avoid or reduce impacts, though they may allow exceptions and require Departmental resources for plan review and compliance measures.
- BMPs that require reports or documentation, suggest limits to certain activities, and/or recommend certain measures are generally expected to have limited effectiveness because they are not prescriptive and can be difficult to verify or enforce.

In cases where there was uncertainty whether the existing laws, regulations, permits, and BMPs would be adequate to protect the respective resources, it was noted in this document.

Development scenarios

Two scenarios developed in consultation with the Departments by Towson University's Regional Economic Studies Institute (RESI) were used to determine if risks to receptors were dependent upon different levels of UGWD. Scenarios 1 and 2 assume 25% and 75% extraction levels, respectively, of the available Marcellus natural gas resource in Maryland. These extraction levels were considered by RESI to be conservative and feasible projections of resource development. To convert these extraction levels to a specific number of wells, RESI used scientific literature values on the total size and productivity of the Marcellus formation, multiplied that by the percentage of the Marcellus underlying Garrett and Allegany counties, divided that by the average productivity per well, and then applied the 25% and 75% extraction levels. Activity scope and duration associated with each different scenario were evaluated during each UGWD phase. Table 1 describes the well and well pad development projections for each scenario. It is important to note that these scenarios, while plausible, were constructed specifically to mimic the "boom and bust" cycle that is associated with most mineral extraction operations. To estimate the pace of well development under each scenario, RESI used historical data on Pennsylvania's drilling activities. The actual pace and intensity of development could differ from these scenarios.

Table 1: Well and Well Pad Development Activity for Scenarios 1 and 2

Item	Scenario 1	Scenario 2
Extraction Level	25%	75%
Wells per pad	6	6
Average Wells Drilled/Year	15	45
Total Wells Drilled	150	450
Total Number of Well Pads	25	75

Additional assumptions were based upon information from New York (NY DEC 2011) and information gathered from UGWD applications submitted to the Departments. (The applications for gas well drilling permits were withdrawn.) These include:

- 15-acres of total site disturbance/land clearing per well pad developed (~4 acres for just the well pad).
- 5,000,000 gallons of water used to hydraulically fracture each well of which 30% (1.5 million gallon) returns as flow back. This information was used to estimate the number of truck trips for delivering freshwater and hauling flowback fluid. This is a conservative assumption as flowback water may be recycled for successive hydraulic fracturing events on a well pad.
- Trucks/Equipment: For each well pad, which supports 6 wells, 9,358 one-way trips for heavy trucks and 3,616 one-way trips for light trucks will be required.

Likewise, existing laws, regulations, permits, and BMPs relating to particular risks (water quality, air quality, noise, waste, etc.) were considered to be protective of, or mitigate risk to, the respective resource/media, when and where appropriate.

Individual risk assessments

In order to ensure comprehensive consideration of potential risks, each team used the UGWD phases described in the next section as the context for evaluating specific activities and corresponding risks. Development scenarios were considered in specific instances when intensity of development had a bearing on the risk level. Each team reviewed current scientific literature on risks associated with activities in each UGWD phase. Current regulations and proposed BMPs were evaluated for their effectiveness in mitigating identified risks. In some team reports, additional mitigation measures are identified.

Based on these criteria and the subject matter expertise of team members, each team performed a qualitative assessment of the probability and consequence for each risk in their assigned category. Probability was categorized as low, medium or high while the consequence was categorized as minor, moderate or serious. Table 2 provides the definitions of the categories. Each risk was then assigned an overall risk rank (low, moderate or high) based on the combination of the probability that an event would occur and the consequence that the event would have on a specific receptor. Those activities with higher probabilities of a more severe consequence were rated as high risk.

Since this is a qualitative risk assessment, there was not sufficient resolution to rank overall risk any more specifically than low, medium or high. Readers can refer to the appendices for additional details on the probability and consequence that determined overall risk rankings. The matrix used to determine the overall risk ranking is presented in Table 3 .

The set of risks identified by the Advisory Commission were considered by the teams and reorganized to the set of risks provided in Appendix A. This risk assessment chart identifies the specific risk aspect (e.g. traffic, waste disposal), the specific risk agent or chemical (e.g. cost of road damage, drilling mud), the impacted receptor (e.g. community, ecological) and then identifies the risk rank (low, moderate, high) for that particular risk during each phase of UGWD. The next section provides an overview of some of the key risks of concern that were assessed under each UGWD phase.

Table 2: Risk Factors Used

Probability	**Definition**
Low	Rarely happens under ordinary conditions; not forecast to be encountered under foreseeable future circumstances in view of current knowledge and existing controls on gas extraction
Medium	Occurs occasionally or could potentially occur under foreseeable circumstances if management or regulatory controls fall below best practice standards
High	Occurs frequently under ordinary conditions
Insufficient Data to Determine	Lack of available data to confidently assign probability
Consequence	**Definition**
Minor	Slight adverse impact on people or the environment; causes no injury or illness
Moderate	Considerable adverse impact on people or the environment; could affect the health of persons in the immediate vicinity; localized or temporary environmental damage
Serious	Major adverse impact on people or the environment; could affect the health of persons in a large area; extensive or permanent environmental damage
Insufficient Data to Determine	Lack of available data to confidently assign consequence

Table 3: Risk Ranking Methodology

Probability →

Consequence ↓

Risk Rank	Low	Medium	High
Minor	Low	Low	Moderate
Moderate	Low	Moderate	High
Serious	Moderate	High	High

Limitations and uncertainty

Risk assessments are an inexact science and inherently fraught with uncertainty. This is particularly true when evaluating an activity that is in its early stages and where the science is still evolving. Also compounding this uncertainty is the fact that states currently allowing UGWD (Pennsylvania, Texas, Colorado, Wyoming, North Dakota) have not implemented the level of regulation proposed in Maryland. This leaves information gaps in terms of BMP risk mitigation effectiveness that Departmental experts must fill with their own professional judgment. Furthermore, the qualitative nature of the assessment and the broad categories developed to assign risk leave some level of individual interpretation when ranking risk.

Having acknowledged these limitations, that does not mean that the risk assessment findings are of no use or should assign everything to an insufficient information category. On the contrary, Maryland's risk assessment process has been successful in differentiating levels of risks and drawing attention to areas where additional best practices or other considerations may be helpful. These uncertainties highlight the critical importance of sufficient monitoring programs and compliance/enforcement mechanisms to better identify and address key risks.

Risk Assessment for Phases of Unconventional Gas Well Development

This section summarizes the key finding from the individual team risk assessments. The full set of risk rankings can be found in Appendix A while additional details regarding assessment of risk factors and application of proposed and existing BMPs can be found in the team reports that are included as Appendices B through J.

Phase 1: Site Identification and Preparation

Many of the team reports assessed the processes associated with site identification and site preparation separately. These two phases are combined for purposes of streamlining presentation of risks in Appendix A.

Activity/Description:

Prior to conducting any drilling activities in a region, oil and gas companies routinely use seismic assessment surveys to target the best locations for drilling exploratory/production wells. Site preparation involves clearing, leveling, and excavation at a well site to install the well pad, freshwater pits, and any associated access roads.

Duration:

Seismic Testing: Up to 120 days, based upon maximum length of time indicated from a draft permit application in Maryland.

Site Preparation: Up to 4 weeks (NY DEC 2011) per multi-well pad

Summary of Risks:

Other than relatively limited diesel emissions no literature could be found identifying risks to human or ecological receptors from seismic assessment activity, so risks for this activity were not assessed. Impacts to communities, people and ecological receptors were low for noise and vibration risks caused by truck traffic and construction activity. Visual impacts from land clearing, pad development and lighting were also ranked low for communities, people and ecological receptors. Contamination of soil, surface or groundwater is generally not a concern during this phase. Risks to people from air emissions were rated as moderate resulting from combustion products and airborne dust from unpaved roads caused by truck traffic. Ecological and farmland impacts associated with clearing land for the construction of new access roads and well pads were rated as moderate due to the likely fragmentation of large blocks of forest, the potential to site well pads on agricultural land and potential stream impacts associated with stream crossings. While the proposed Comprehensive Gas Development Plan and the suite of location restrictions and setbacks will significantly reduce the degree of forest fragmentation and stream impacts, impacts are still expected to occur, but on a localized basis, due to the widespread presence of many sensitive streams and large forested landscapes.

Team Reports:

Appendix B: Air Emissions, Appendix C: Road Damage and Traffic, Appendix F: Noise and Visual

Phase 2: Drilling

Activity/Description:

After the site has been prepared and the drilling pad installed, one or more drill rigs are brought on site to conduct well drilling. Within Maryland, the Marcellus shale formation runs from the land surface to 9,000 feet below ground. Drilling entails creating a vertical bore hole until the bit approaches the Marcellus shale, then turning the drill bit and drilling horizontally through the shale for distances that can extend over a mile. The hole is then cased and cemented. Typically, three levels of casing (surface, intermediate, and production) are used in a telescoping fashion. The surface casing is run from the land surface to below the deepest freshwater layer. The intermediate casing is run from the surface casing down to the target formation. The production casing is run from the intermediate casing through the target formation and is perforated to allow gas to flow through. All casing strings are cemented in place to stabilize the casing string and also seal the annular space between the casing and borehole to prevent gas or fluid migration between geologic strata.

Duration:

Up to 5 weeks per well (NY DEC 2011).

Summary of Risks:

Impacts to communities, people and ecological receptors were low for noise and vibration risks caused by drilling, casing, cementing activities and other ancillary. Risks associated with increased truck traffic during this phase are anticipated to pose moderate risks to communities and people from noise and vibrations, accidents and damages to vehicles, delays and inconvenience, loss of rural character and other impacts. There is a high risk that costly road repairs will be needed. During the drilling phase, materials (fluids and chemical additives) are brought on to the site, stored (both before and after use), used for drilling and then recycled or transported offsite for appropriate disposal. The high standards set for casing and cementing practices, management of materials and wastes on and off the site and careful siting resulting from location restrictions, setbacks and geologic studies, yield a low risk that ground and surface water supplies will be impacted either through surface spills or subsurface releases during the drilling and waste transport process. Risks from air emissions to humans were moderate resulting from the probability that NOx, benzene and particulate matter would be emitted from diesel engines used to power drill rigs and compressors. Air emissions from non-combustion sources such as tanks or spills were rated as low. However, insufficient consequence data were available to assign a risk ranking to air emissions associated with truck traffic.

Team Reports:

Appendix B: Air Emissions, Appendix C: Road Damage and Traffic, Appendix D: Drilling Fluids and Cuttings, Appendix F: Noise and Visual, Appendix H: Wells and Formations, Appendix I: Waste

Phase 3: Hydraulic Fracturing/Completion

Activity/Description:

During hydraulic fracturing, the horizontal section of the well is perforated by a series of explosive charges that create small fractures in the target formation in preparation for hydraulic fracturing. Then millions of gallons of water, added chemicals and particles known as proppant (usually sand that is mainly silicon dioxide) are pumped down the well at high pressure to further fracture the shale. As the hydraulic fracturing water penetrates and enlarges the initial fractures created by the explosive charges, the included proppant fills the interstitial spaces of the created fractures and keeps them propped open so that produced gas can flow into the well. Once fracturing is complete, some of the injected fracturing fluids return to the surface as flowback. During the flowback period both hydraulic fracturing fluids and other naturally occurring materials contained in the formation migrate back through the borehole to the surface as a result of the overlying geological pressure. Pipelines (gathering lines) that transfer the gas to intrastate or interstate pipelines can be installed during this phase, but the impact of gathering lines is addressed in connection with the production phase.

Duration:

Hydraulic Fracturing: 5 days per well for the actual fracturing - 2 days to mobilize and demobilize hydraulic fracturing equipment. (NY DEC 2011)

Flowback: 3-10 days (average 6.5 days/well, U.S. EPA 2012)

Venting/Flaring: 1 day to several weeks (U.S. EPA 2011) and completely or partially overlaps with the flowback phase.

Summary of Risks:

Truck traffic is most intense during this phase of UGWD because of the numerous tank truck loads of water that must be brought to the site for hydraulic fracturing. Although centralized water supply facilities and pipelines are increasingly being used to deliver water to well sites, the risk assessment did not assume this will occur. For this reason, risks to communities and people from truck traffic are ranked high due to the noise, vibration and cost to repair road damage. Other factors related to traffic such as accidents, damage to vehicles, delays and inconvenience continue to be moderate. There are concerns over the toxicity of chemicals used in hydraulic fracturing fluid and the potential for contamination of drinking water, surface water and ground water supplies. Pathways of contamination include spills, both on the pad and off the pad, subsurface releases from poorly constructed wells and improper management and transport of waste materials, both on the pad and off. The stringent controls on well casing and cementing, stormwater and spill management on the pad, proper siting using geologic studies and setbacks from sensitive ecological and community features are among the many best practices that reduce surface and ground water risks for people and the environment to low.

The sources of air emissions increase during this phase to include inhalation of the silica proppant and additional combustion and non-combustions sources of air emissions required for hydraulic fracturing pumps and flaring events. Under the 75% extraction scenario, air emissions risks rise to high for both combustion and non-combustion emissions compared to the moderate risk ranking under the 25% extraction scenario because the activity will occur more often under the more intense development scenario. Reduced emissions completions, controls on hydraulic fracturing fluid tank emissions, and limits on flaring with help reduce risks associated with these emissions. In addition, water appropriations pose a moderate risk to aquatic ecosystems because of the withdrawals of large amounts of water over compressed periods of time. There are uncertainties regarding how this may impact aquatic ecosystems which reflect sensitivities associated with time of year, breeding and spawning periods and drought conditions.

Team Reports:

Appendix B: Air Emissions, Appendix C: Roads and Traffic, Appendix E: Hydraulic Fracturing Fluids, Appendix F: Noise and Visual, Appendix G: Water Withdrawal, Appendix H: Wells and Formations, Appendix I: Waste

Phase 4: Production

Activity/Description:

Pipelines are needed to transmit the gas from the well to processing plants or intrastate or interstate transmission lines. Compressors may be necessary on site to provide the pressure necessary to move the gas through the gathering lines. Offsite compressors are also required to maintain necessary pressures to deliver gas to processing plants or intrastate or interstate pipelines. In addition, produced gas may need additional processing to prevent condensation/crystallization of liquid compounds in the gas gathering lines. This processing may occur both on-site, known as field processing, and off-site at centralized processing plants.

Central processing plants provide further treatment to remove remaining liquids and to achieve desired methane concentrations. Downstream infrastructure such as liquefaction plants, central processing plants, transmission lines, etc. are outside the scope of this risk assessment.

Duration:

Approximately 20 years or more, although this is highly variable

Risk Summary:

During this phase, or possibly initiated in earlier stages, gas gathering lines will be installed to transport gas. Johnson (2010) estimates that 1.65 miles of gathering pipeline are needed for each new well pad. In Pennsylvania, this aggregate effect will impact an area larger than the cumulative area affected by all other Marcellus gas infrastructure and about half of that area will be forested. While the Comprehensive Gas Development Plan will serve to reduce the number of gathering lines installed and will minimize forest fragmentation through co-location with other linear infrastructure, there will be, by necessity and practicality, significant impacts to terrestrial and aquatic ecosystems. These risks to ecology have been rated moderate (under the 25% extraction scenario) to high (under the 75% extraction scenario) because the siting of gathering lines is not regulated and is dictated by the willingness of property owners to enter into lease or easement agreements. In addition, gathering lines are long term features on the landscape (spanning the production life of the well) and the likelihood of stream crossings is high. Compressors on and off the pad pose low to moderate risks to humans while impacts related to truck traffic are either non-existent or low. Subsurface releases of stray gas and fluids continue to be a risk to both humans and ecology. The stringent controls on well casing and cementing, stormwater and spill management on the pad, proper siting using geologic studies and setbacks from sensitive ecological and community features are among the many best practices that serve to reduce the risk of water contamination for human consumption to low except for the specific case of methane. Risks were evaluated for setbacks of 2,000 feet and 3,281 feet (1 kilometer) from the nearest drinking water wells. Risks to humans were rated as moderate for the 2,000 feet scenario because data are emerging that have found higher concentration of dissolved methane in drinking water wells closer to gas wells. Moderate risks associated with subsurface releases of fracturing fluid, flowback and produced water were noted for aquatic communities because these contaminants would be expected to remain in the groundwater and because of the sensitivity of pollution-intolerant aquatic life to low concentrations of salt and other chemicals. Insufficient data were available on the health consequences of air emissions produced from compressors because of uncertainties associated with location, fuel type and number needed. Moderate risks for air emissions were associated with high probabilities of exposure to combustion and non-combustion sources related to well pad and pipeline emissions, well unloadings. The consequences of truck traffic were determined to be minor.

Team Report:

Appendix B: Air Emissions, Appendix C: Roads and Traffic, Appendix F: Noise and Visual, Appendix G: Wells and Formations, Appendix I: Water Withdrawal

Phase 5: Well Abandonment/Reclamation

This phase was not assessed by all the teams but is included in the core document and risk assessment chart in Appendix A to address the entire lifecycle of the well pad.

Activity/Description

The goal of reclamation is to return the developed area to native vegetation (or pre-disturbance vegetation in the case of agricultural land) and restore the original hydrologic conditions to the maximum extent possible. Interim reclamation will follow construction and drilling to stabilize the ground and reduce opportunities for invasive species.

Duration

Interim reclamation follows immediately after last well on a pad moves into production. Final reclamation will occur over a 4 week period.

Risk Summary:

Air, water and soil contamination risks related to subsurface leaks in wells are low for both humans and ecology. Procedures for well plugging and abandonment are prescribed in COMAR 26.19.01.12 in order to prevent migration of stray gas along the wellbore and behind casing. Maryland's best practices applies reclamation requirements to all disturbed land, including the pad, access roads, ponds, pipelines and locations of ancillary equipment which reduces the ecological and visual impacts associated with land clearing and forest fragmentation. Truck traffic and noise associated with reclamation activities will occur but will be minimal, posing low risks people, communities, wildlife and recreation.

Conclusion

The risks that ranked highest during UGWD related to road damage and traffic accident risks, forest fragmentation risks associated with gas gathering lines, air emissions and traffic noise. Risks of methane contamination in surface or groundwater due to improperly constructed wells were moderate, but further reduced to low with 1 kilometer setbacks. Water withdrawal risks were considered moderate during critical low flow periods, but otherwise low. Risks to surface or groundwater contamination from chemical spills either on the well pad or during transport were generally considered low. Waste disposal risks were likewise considered low as a result of currently robust regulations. Air emissions associated with vehicle traffic had insufficient information to assess risk.

Risks are inherent in any type of mineral extraction, industrial and construction activity. Across the life-cycle of the well, from initial site identification to well abandonment and reclamation, UGWD encompasses a broad range of these activities. Maryland draws from its robust stormwater management, soil erosion and control, and water appropriations programs and examines the effectiveness of proposed best management practices for revising its existing gas and oil development regulations. Together, these existing and proposed practices serve to reduce many risks to Western Maryland's citizens, economy and its high quality water, air and natural resources. If risks are found to be unacceptably high, additional mitigation steps could be taken, or gas extraction in the Marcellus shale in Maryland could be deferred until risks can be reduced by new technology or practices, or until additional data demonstrate that the proposed practices are effective to reduce risk.

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