A REPORT ON THE REGULATION AND SAFETY OF HYDRAULIC FRACTURING FOR OIL OR NATURAL GAS RECOVERY

A REPORT FOR:

HOUSE AND SENATE COMMITTEES ON NATURAL RESOURCES AND ENERGY AND THE HOUSE COMMITTEE ON FISH, WILDLIFE AND WATER RESOURCES

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PREPARED BY:

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Executive Summary

High volume hydraulic fracturing (HVHF) is a well-stimulation technique in which rock is fractured by a hydraulically pressurized liquid. A fluid (gas, liquid, foam) with a mix of additives and proppant is injected into a wellbore to create cracks in the rock formation through which natural gas, petroleum, and brine will flow more freely. When the pressure is removed from the well, the proppant, such as sand, hold the fractures open.

The State of Vermont has enacted laws and rules prohibiting this hydraulic fracturing for oil and gas in Vermont due to the evidence of risks to human health and the environment. In accordance with Sections five (5) through seven (7) of Bill H.464 which passed the Vermont House and Senate in 2012, the research summarized in this report concerns the regulation and safety of hydraulic fracturing for oil or natural gas recovery.

Research involved:

- A review of existing applicable State resources, laws, rules and regulations;
- Additional resources, laws, rules and regulations that would be required to address hydraulic fracturing and associated activities; and,
- Consultations with interested parties, including representatives of environmental groups, the oil and gas board, the oil and gas industry, and the U.S. Environmental Protection Agency, as accessible.

Reports from other States providing relevant information were also reviewed.

Questions were posed by the legislature through H.464. Responses are simplified below followed by a summary of key findings. The report elaborates on these questions and findings expanding the response to address HVHF if it were allowed sometime in the future.

H.464 Sec. 5. AGENCY OF NATURAL RESOURCES REPORT; REGULATION OF HYDRAULIC FRACTURING FOR OIL OR NATURAL GAS RECOVERY

(a) On or before January 15, 2015, the Secretary of Natural Resources shall submit to the Senate and House Committees on Natural Resources and Energy and the House Committee on Fish, Wildlife and Water Resources a report recommending how hydraulic fracturing should be regulated in the state. The report shall include:

(1) A recommendation of what state agency, board, or instrumentality should be authorized by the general assembly to regulate hydraulic fracturing in the state;

Response: The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. With input from the Senate Natural Resources and Energy Committee, Vermont Statute 29 V.S.A. Chapter 14, was modified effective May 16, 2012, with the following: (a) No person may engage in hydraulic fracturing in the State (b) No person within the State may collect, store, or treat wastewater from hydraulic fracturing. Furthermore, the Underground Injection Control (UIC) Regulations under Chapter 11 of the Environmental Protection Rules were amended and became effective October 29, 2014. The amended Rules provide the following, prohibiting fracking in the State: (a)No person shall construct, operate, maintain, or convert any Class I, Class II, or Class III well. (c) No person shall construct, operate, maintain, modify, or convert a Class V well that receives waste from the location within a facility or business where the following occurs: (14) hydraulic fracturing used to extract natural gas or oil. As such, no state agency, board or instrumentality is authorized to allow hydraulic fracturing in the state.

In the event that HVHF were allowed in the future, generally speaking, hydraulic fracturing for oil and gas production wells is typically addressed by state oil and gas boards or equivalent state natural resource agencies. State oil and gas boards or agencies may have additional regulations for hydraulic fracturing. The State of Vermont has in place the relevant boards and agencies to regulate hydraulic fracturing in the State.

(2) A summary of how the Agency recommends that hydraulic fracturing be regulated in the state, including how hydraulic fracturing should be permitted, where and how hydraulic fracturing should be sited, how waste from the hydraulic fracturing should be disposed of, how groundwater and surface water withdrawal for hydraulic fracturing should be regulated, and how to regulate land use practices and traffic associated with hydraulic fracturing.

Response: The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. Class II Waste injection wells for the injection of liquid wastes generated through hydraulic fracturing of oil and gas bearing formations are also prohibited in the State of Vermont. As such, there is no regulating or permitting of HVHF or associated activities including the generation, storage, transport or disposal of waste, groundwater or surface water withdrawals, land use practices or traffic associated with hydraulic fracturing for oil and gas in the Vermont.

The most favorable geologic setting for an oil and gas well is where oil and gas is found. Potential gas bearing shales are limited to the Lake Champlain Basin in western Vermont. Limited testing of rocks in Vermont suggests that gas is not present or is present at insignificant concentrations well below what would be considered an economically viable resource. Furthermore, Lake Champlain is a valued natural resource which serves as a drinking water supply for numerous communities and is a major recreation and tourism destination. The Lake Champlain Basin would not be a suitable location for oil and gas exploration and extraction activities including HVHF. Our recommendation is that this prohibition remain in place.

In the event that the Vermont Legislature decides to allow hydraulic fracturing at some time in the future, and economically viable resources were identified outside the Champlain Basin, the Natural Gas and Oil Resources Board (NGORB) would need to be reactivated to issue permits in conjunction with the Natural Resources Board (NRB)/Act 250, the ANR and local municipalities.

(3) Whether the Agency of Natural Resources recommends that additional statutory or regulatory authority be enacted or adopted for the regulation of hydraulic fracturing and, if additional authority is recommended, a summary of the recommended authority.

Response: The State of Vermont has enacted laws (29 V.S.A) and rules (UIC Rules) prohibiting hydraulic fracturing for oil and gas in Vermont. As such, there are no additional statutory or regulatory authority recommendations at this time.

If the State of Vermont were to repeal 29 V.S.A. and allow HVHF or associated activities such as waste disposal, the UIC Rule would require major revisions. Extensive regulations would be promulgated and additional staff resources would be required throughout the Agency of Natural Resources.

(b) In preparing the report required by this section, the Secretary of Natural Resources shall consult with interested parties, including representatives of environmental groups, the oil and gas board, the oil and gas industry, and the U.S. Environmental Protection Agency.

Response: This section of the report was prepared based on review/research and/or consultation with environmental groups, the Vermont Oil and Gas Board, the U.S. EPA and to a lesser degree, the oil and gas industry. In addition, reports prepared by Oil and Gas producing states and numerous laws, rules and regulations were also reviewed.

H.464 Sec. 6. ANR REPORT ON SAFETY OF HYDRAULIC FRACTURING

On or before January 15, 2016, the Secretary of Natural Resources shall report to the Senate and House Committees on Natural Resources and Energy and the House Committee on Fish, Wildlife and Water Resources regarding the environmental impacts of hydraulic fracturing and the potential impact of the practice on the public health and environment of Vermont. The report shall include:

(1) A summary of the findings of the U.S. Environmental Protection Agency studies of the environmental impacts of hydraulic fracturing, including the effects of hydraulic fracturing on groundwater and air quality;

Response: EPA published the coalbed methane study, Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs (EPA 816-R-04-003) in 2004. EPA concluded that there was little to no risk of fracturing fluid contaminating underground sources of drinking water during hydraulic fracturing of coalbed methane production wells.

The report was criticized by longtime EPA scientist Weston Wilson who wrote to Colorado representatives stating that the report is “unsound”, invoking protections under the First Amendment of the Constitution and the Whistleblowers Protection Act should EPA retaliate against him.

In response to escalating public concerns and the anticipated growth in oil and natural gas exploration and production, the US Congress directed EPA in fiscal year 2010 to conduct research to examine the relationship between hydraulic fracturing and drinking water resources. A Progress Report was published in 2012. This report primarily provides an update of the methods used for the investigation and progress to date, but provides limited actual data or results.

The EPA report completion target date was 2014 but has not been published as of this writing. The current schedule for release of the draft Report of Results to the public is early in 2015, as noted by EPA Administrator Gina McCarthy in a September 16, 2014 Inside EPA daily journal article. (Ed Hanlon, pers. comm. 2014)

(2) A summary of additional relevant peer review studies related to the environmental impacts of hydraulic fracturing when, in the discretion of the Secretary of Natural Resources, they are determined to be instructive or relevant to the potential environmental impacts of hydraulic fracturing in Vermont.

Response: The Generic Environmental Impact Statement (GEIS) was developed in 1992 by New York State Department of Environmental Conservation (NYSDEC) and has evolved to address HVHF into a Draft Supplemental Generic Environmental Impact Statement (SGEIS). Environmental impacts associated with unconventional HVHF on various media are presented in Chapter 6 of the SGEIS and was used as a back drop for the environmental impact section of this report.

In December, 2014 New York State Department of Health issued their report “A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development”, which was reviewed and summarized.

The following peer reviewed articles were studied and are summarized in the report:

> R.D. Vidic, S. B. (2013, May 17). Impact of Shale Gas Development on Regional Water Quality. Science. doi:10.1126/science.1235009

Susan L. Brantley, D. Y. (2014, June 1). Water Resource Impacts During Unconventional Shale Gas Development:The Pennsylvania experience. International Journal of Coal Geology, 126, 140-156.

Jackson, R.E. et al. (2013, July-August). Groundwater Protection and Unconventional Gas Extraction: The Critical Need for Field-Based Hydrogeological Research. *Groundwater, 51*, 488-510.

Additional articles were reviewed and are referenced throughout the report.

(3) A recommendation as to whether the prohibition on hydraulic fracturing under 29 V.S.A § 571 should be repealed.

***Response**:* At the present time the Agency of Natural Resources –Department of Environmental Conservation does not have sufficient evidence that hydraulic fracturing for oil and gas can be conducted without risk of contamination to the groundwater of Vermont. In fact, the evidence suggests that the practice of hydraulic fracturing has significant potential to cause both groundwater contamination and degradation of air quality, if any of the risks are improperly managed or controlled. Therefore, it is our recommendation that the prohibition on hydraulic fracturing for oil and natural gas recovery be continued.

H. 464 Sec. 7. AGENCY OF NATURAL RESOURCES; UNDERGROUND INJECTION CONTROL RULEMAKING

On or before July 15, 2015, the Secretary of Natural Resources shall amend the rules regulating the discharge of waste into an injection well, including those discharges into an injection well for oil and gas recovery for which the Agency of Natural Resources has jurisdiction, in order to update the rules to reflect existing requirements under federal and state law and to address practices not contemplated by the existing rules. In amending the rules regulating the discharge of waste into an injection well, the Agency of Natural Resources shall provide that no permit shall be issued under 10 V.S.A. chapter 47 for a discharge of waste into an injection well when such a discharge would endanger an underground source of drinking water.

Response: The Underground Injection Control Regulations under Chapter 11 of the Environmental Protection Rules were amended and became effective October 29, 2014. The following prohibitions pertaining to the potential for hydraulic fracturing for the purposes of oil and gas recovery were included in the Rule Amendment:

> Under Subchapter 3 Prohibitions; Permit Required; Exemptions, Section §11-301 Prohibitions
>
> (a) No person shall construct, operate, maintain, or convert any Class I, Class II, or Class III well.
>
> (c) No person shall construct, operate, maintain, modify, or convert a Class V well that receives waste from the location within a facility or business where the following occurs:
>
> (14) Hydraulic fracturing used to extract natural gas or oil.

Class II Waste injection wells are used for the injection of liquid wastes generated through hydraulic fracturing of oil and gas bearing formations and are now prohibited in the State of Vermont.

Class V wells are prohibited at any site involved in hydraulic fracturing for oil and gas.

Additional report highlights are summarized below:

- Modifications to hydraulic fracturing and horizontal drilling techniques, both long-used in the oil and gas industry, have resulted in an all-time peak in natural gas production in the U.S. The Marcellus Shale gas production "play" is the largest and fastest growing shale gas play in the U.S, stretching from New York State to southern West Virginia and west to Ohio, with most production coming from Pennsylvania. The Marcellus Shale does not extend to Vermont.
- The modified techniques involves injecting millions of gallons of fluid, typically 99% water and 1% proprietary chemicals and a proppant, typically sand, thousands of feet below the surface under extreme pressures. The proprietary chemicals are exempt from federal disclosure requirements. Numerous concerns arise from activities associated with high volume hydraulic fracturing (HVHF) for oil and gas. The millions of gallons of water that are needed must be transported to the well pad site, stored for use, mixed on-site with toxic chemicals, recovered from the well after they are injected and handled as contaminated or hazardous waste and transported from the site, often a considerable distance, for disposal. Thousands of light and heavy duty truck trips are required for each frack, some wells are fracked numerous times and often there are multiple wells per pad. The oil and natural gas industry also is a significant source of emissions of methane, a greenhouse gas that is more than 20 times as potent as carbon dioxide. Emissions of air toxics such as benzene, ethylbenzene, and n-hexane, also come from this industry. Air toxics are pollutants known, or suspected of causing cancer and other serious health effects.
- Hydraulic fracturing for oil and gas is exempt from UIC permitting by the Energy Act of 2005, except where diesel fuel is used as an injection fluid, or where produced waters (waste fluids generated during gas production) are re-injected into the subsurface for disposal. Vermont State Agencies or Boards which would be involved in HVHF for oil and gas would include the Vermont Natural Gas and Oil Conservation Act and the Natural Gas and Oil Resources Board, Act 250 and the NRB and the Agency of Natural Resources (ANR).
- Despite the numerous loop holes, regulators (local, state and federal) and stake holders including environmental organizations and the oil and gas industry are working to identify, characterize, quantify and mitigate waste and risks to the public health and environment in pursuit of their various objectives.
- The Groundwater Protection Council conducted a 5 year study following 29 Oil and Gas States and the development of regulatory requirements pertaining to oil and gas drilling. Several improvements in permitting and regulation of fracking in the oil and gas states are described under the following categories:
    - *Permitting Requirements*
    - *Formation Treatment/Stimulation/Fracturing*
    - *Well Integrity*
    - *Temporary Abandonment*
    - *Well Plugging*
    - *Storage in Pits*
    - *Storage in Tanks*
    - *Transportation of Produced Water for Disposal*
    - *Produced Water Recycling and Reuse*

    - *Exempt Waste Disposal*
    - *Spill Response*
    - *Water Sampling and Analysis*

- Still there appears to be much work to be done to improve and enforce regulation throughout all the oil and gas producing and waste handling states.
- The Sierra Club promotes tough federal and state safeguards and repealing the numerous federal exemptions that the oil and gas industry enjoys. They also strive to support local communities that wish to restrict gas development and ensure that gas development is not allowed in areas that are environmentally inappropriate. The Club's Fracking Policy encourages ongoing improvements in projects and regulations consistent with environmental progress.
- The Clean Water Action and Clean Water Fund (CWA/CWF) recently published two reports that discuss the inadequacies of the Aquifer Exemption Program and the UIC Class II Program to protect drinking water from certain oil and gas and uranium mining activities under the Safe Drinking Water Act (SDWA). These two publications highlight Congressional and regulatory exceptions to these programs and concern that the depth and quality of an aquifer which could potentially serve as an underground source of drinking water is far different from when the program was first developed over thirty years ago. EPA officials recognize that advancing technology and climate change have made water sources once deemed inaccessible more likely to be needed, and used, in the future.
- The EPA is wrapping up an extensive study that began in 2011 to study the impacts of hydraulic fracturing on Drinking Water Resources. The results are past due and are now expected in early 2015. The scope of the research includes the hydraulic fracturing water use lifecycle, which begins with water acquisition from surface or ground water and ends with discharge into surface waters or injection into deep wells.
- The EPA published a Progress Report in 2012 which contained primarily an update of sampling protocols used and laboratory methods developed offering little in terms of data results or conclusions at this time. The following is an explanation of a significant water quality issue from the report which describes how wastewater from HVHF is mixing with sources of drinking water: Wastewaters from hydraulic fracturing processes typically contain high concentrations of total dissolved solids (TDS), including significant concentrations of chloride and bromide. These halogens are difficult to remove from wastewater; if discharged from treatment works, they can elevate chloride and bromide concentrations in drinking water sources. Upon chlorination at a drinking water treatment facility, chloride and bromide can react with naturally occurring organic matter (NOM) in the water and lead to the formation of disinfection byproducts (DBPs). Because of their carcinogenicity and reproductive and developmental affects, the maximum contaminant levels (MCLs) of the DBPs bromate, chlorite, haloacetic acids, and total Trihalomethanes (THMs) in finished drinking water are regulated by the National Primary Drinking Water Regulations. Increased bromide concentrations in drinking water resources can lead to greater total THM concentrations on a mass basis and may make it difficult for some public water supplies (PWSs) to meet the regulatory limits of total THM. It is important to note that hydraulic fracturing wastewater can potentially contain other contaminants in significant concentrations that could affect human health. The EPA identified the impacts of elevated bromide and chloride levels in surface water from hydraulic fracturing wastewater discharge as a priority for protection of public water supplies.

- As part of the report process, EPA has received comments from stakeholders including the oil and gas industry. American Petroleum Institute submitted joint comments representing multiple organizations from the oil and gas industry. The technical comments provided were related to the EPAs stated purpose, scope, systematic planning, quality and context of the report.
- Regarding air quality, the EPA reports that industry is the largest industrial source of emissions of volatile organic compounds (VOCs), a group of chemicals that contribute to the formation of ground-level ozone (smog). Exposure to ozone is linked to a wide range of health effects, including aggravated asthma, increased emergency room visits and hospital admissions, and premature death. EPA estimates VOC emission from the oil & natural gas industry at 2.2 million tons a year in 2008.
- The oil and natural gas industry also is a significant source of emissions of methane, a greenhouse gas that is more than 20 times as potent as carbon dioxide. Emissions of air toxics such as benzene, ethylbenzene, and n-hexane, also come from this industry. Air toxics are pollutants known, or suspected of causing cancer and other serious health effects.
- On April 17, 2012, the U.S. Environmental Protection Agency (EPA) issued regulations, required by the Clean Air Act, to reduce harmful air pollution from the oil and natural gas industry. The final rules include the first federal air standards for natural gas wells that are hydraulically fractured, along with requirements for several other sources of pollution in the oil and gas industry not previously regulated at the federal level. The final rules are expected to yield a nearly 95 percent reduction in VOC emissions annually primarily through capturing natural gas that escapes into the air, and making that gas available for sale. The rules also will reduce air toxics, which are known or suspected of causing cancer and other serious health effects, and emissions of methane, a potent greenhouse gas.
- A Draft Supplemental Generic Environmental Impact Statement (dSGEIS) was published by the State of New York in 2011. New York continues to have a moratorium on HVHF for oil and gas until, essentially, environmental and public health concerns can be mitigated or avoided. A Final SGEIS was not available at the time of this writing. The dSGEIS provides a comprehensive overview of environmental and public health concerns associated with HVHF and provides a backdrop for environmental and socioeconomic impacts this report.
- The New York State (NYS) Department of Health (DOH) recently released its Public Health Review of HVHF for Shale Gas recommending that HVHF should not proceed in NYS. The task as described by NYS Acting Commissioner of Health, Howard A. Zucker, M.D., J.D., who assumed responsibility of the report when the previous commissioner left, was to “consider, more broadly, the current state of science regarding HVHF and public health risks”. More than 20 DOH Senior Research Scientists, Public Health Specialists, and Radiological Health Specialists contributed to the review, under the direction of the former and acting Commissioners of Health. In addition to evaluating published literature, Commissioners and DOH staff held multiple discussions and meetings with public health and environmental authorities in several states to understand their experience with HVHF. The Commissioners also met with researchers from academic institutions and government agencies to learn more about planned and ongoing studies and assessments on the public health implications on HVHF. Review letters with valuable input from the Health Specialists are included in the report. A strong partnership between the DOH, NYS DEC and local government bodies is emphasized throughout the Health

Specialists' comments. Other relevant literature, focused on HVHF and effects on environmental media, was also reviewed. The report includes 65 pages of varied and relevant abstracts. Findings concerning air, water-quality, seismic, community impacts and health outcomes are included in the report. The DOH report describes numerous studies and findings but consistently raises concerns about the strength of the study's conclusions. According to the DOH, systematic, comprehensive, long-term, longitudinal studies that could contribute to the understanding of the complex relationships of HVHF and public health are needed. Several studies are underway and are described in the DOH report, many of which will not be completed for several years.

- R.E. Jackson outlines the critical need for field-based hydrogeologic research in response to activities associated with unconventional gas extraction. Recent advances in directional drilling technology permits up to 20 horizontal wells to be drilled from a single well pad. Deep and long horizontal wells, up to 9,000 feet in horizontal length combined with multistage hydraulic fracturing can now exploit relatively thin formations containing unconventional hydrocarbons resources (tight shales and sandstones). This ability has increased the supply of natural gas and gas use in North America.

  Public concerns and moratoria imposed by some states and countries are pending further understanding of the environmental and public health impacts. The report outlines the nature of HVHF activities, potential shallow contamination pathways and factors leading to aquifer vulnerability. The author emphasizes that many problems are not associated only with unconventional drilling, but conventional drilling techniques too. Hydraulic fracturing in vertical/conventional boreholes has been used since the 1940's.

  The importance of widely accepted methodology for monitoring is emphasized. The hydrogeologic community has expertise studying fate and transport of relevant chemicals in groundwater including attenuation by dispersion, sorption and biodegradation (of brine, salts and aromatic hydrocarbons). There is little or no peer-reviewed and public data regarding groundwater occurrence and fate and transport of other anthropogenic chemicals used in unconventional natural gas production such as glycols, amines, metal complexes used as corrosion prohibitors, proprietary chemicals or metabolites or degradates that may form from these chemicals such as acrylamide. Peer review and monitoring data is sparse and generally related to spill incidents. To support sustainable development of unconventional gas and protection of groundwater resources the author recommends areas of hydrogeologic research to address science gaps.
- Based on a review of publicly available database resources, Susan L. Brantley, the author of Water Resource Impacts during unconventional shale gas development: The Pennsylvania Experience, concluded that minor violations and temporary problems were reported, but that the "fast" shale-gas start may have led to relatively few environmental incidents of significant impact compare to the number of wells drilled, however, the impact remains difficult to assess due to the lack of transparent and accessible data. Incidents of methane migration due to shale gas activity have been identified. Methane is present naturally due to both high-temperature maturation of organic matter at depth (thermogenic) and low-temperature bacteria processes (biogenic). Regardless of the source, methane will migrate upward through faults and along

fractures from depth or laterally from swamps or glacial till. Methane can also be derived from anthropogenic sources such as landfills and gas pipelines. If methane enters wells as a solute it will off gas due to its low solubility and it is not regulated as a health hazard. However, if it accumulates at high enough concentrations, it can cause an explosion.

- R. D. Vidic adds that although understanding the source of methane may lead to solutions to the problem, the source does not affect liability because gas companies are responsible if it can be shown that any gas, not just methane, has moved into the water well because of shale-gas development. For example, drilling can open surficial fractures that allow preexisting native gas to leak into water wells. This means pre and post data is necessary to determine "culpability".
- Vermont has banned hydraulic fracturing for natural gas in the state. However, the issues associated with the practice are far reaching in terms of the availability of natural gas, distribution, economics and environmental impacts and warrant Vermont's continued attention.

A. Introduction

(1) Hydraulic Fracturing Technique

Hydraulic fracturing (or fracking) is a procedure used to increase the flow of oil or natural gas from a well drilled into a low permeability rock formation and has been in use in the U.S. since the 1940s. (1) However, shales are different than conventional hydrocarbon reservoirs, characterized by extremely low permeability that does not lend itself to conventional fracking processes as readily.

During the development of the Barnett Shale in Texas in the 1990s, a technique suitable for fracking shale was developed. (2) In hydraulic fracturing of deep shale gas zones, the water is commonly mixed with a friction-reducer to lessen the resistance of the fluid moving through the casing, biocides to prevent bacterial growth, scale inhibitors to prevent buildup of scale, and proppants, such as sand or ceramic beads, to hold the fractures open. This type of fracturing process is often referred to as a "slickwater" fracture. (3) The intent is to create a network of interconnected fractures, held open by the proppants which allow oil and natural gas to flow from the pore spaces in the rock to the production well. (1) Slickwater fracs maximize the length of horizontal fractures while minimizing the vertical fracture height, resulting in greater gas mobility and more efficient recovery of a larger volume of gas. (2)

Another technique that has become useful in producing shale gas is horizontal drilling. The first horizontal well was drilled in Texas in 1929, but it took until the 1980s for the technology to be improved enough to become standard industry practice. The technique involves drilling a hole several hundred feet above the target reservoir; then directing the drill bit through an arc (starting at a "kicking point") until it is drilling sideways instead of downward. This has several advantages: 1) it increases the amount of reservoir penetrated from a few tens of feet to several thousand feet; 2) it increases the number of fractures penetrated; and 3) it can be used to develop hydrocarbon resources beneath sensitive areas such as wetlands and a city where a drilling rig cannot be set up. (2)

The slickwater fracture process along with horizontal drilling has turned otherwise unproductive shale formations into the largest oil and natural gas fields in the world. As of 2005, approximately 90 percent of all oil and natural gas wells drilled in the U.S. used hydraulic fracturing. (1)

Prior to fracking, a borehole is drilled and well casing is installed. During installation, several sections (i.e. strings) of steel casing are installed telescopically in boreholes to various depths depending upon the geology: 1) conductor casing, the largest casing with largest diameter (~20 in.), is set through the overburden; 2) surface casing (~16 in.) is installed through the groundwater zone, typically to 500 ft. or more below grade; 3) coal protection casing (the same as surface casing or smaller) is installed through coal seams; 4) intermediate casing (~9 in.) may be installed to seal off oil, gas, or brine-bearing zones in the upper several thousand feet; 5) production casing (~5.5 in.) is used to the bottom of the well. The borehole diameter is typically several inches larger than the diameter of the steel casing inside it; therefore, cement grout and/or other sealants are installed around the outside of each casing string to seal the annular gap between the pipe and the rock. Cement is pumped down the center of the casing and pushed out the bottom and around the outside of the casing. This emplacement method maximizes the cement coverage and stops leakage of hydrocarbons or brines; however, physical limitations in some cases result in only a partial seal. It is critical to center the casing in the borehole so that the cement is even in thickness. Irregularities in the wellbore can make proper cement placement difficult [(4)]

Hydraulic fracturing fluids are usually water-based, with approximately 90% of the injected fluid composed of water. Estimates of water needs per well have been reported to range from 65,000 gallons for coalbed methane (CBM) production up to 13 million gallons for shale gas production, depending on the characteristics of the formation being fractured and the design of the production well and fracturing operation. The source of the water may vary but is typically ground water, surface water, or treated wastewater. Industry trends suggest a recent shift to using treated and recycled produced water (or other treated wastewaters) as base fluids in hydraulic fracturing operations. [(5)]

Once onsite, water is mixed with chemicals to create the hydraulic fracturing fluid that is pumped down the well under high pressure (480-850 bar). [(6)] The fluid serves two purposes; to create pressure to propagate fractures and to carry the proppant into the fracture. Chemicals are added to the fluid to change its properties (e.g., viscosity, pH) in order to optimize the performance of the fluid. Roughly1% of water-based hydraulic fracturing fluids are composed of various chemicals, which is equivalent to 50,000 gallons for a shale gas well that uses 5 million gallons of fluid. The hydraulic fracturing fluid is pumped down the well at pressures great enough to fracture the oil-or gas-containing rock formation [(5)]

When the injection pressure is reduced, the direction of fluid flow reverses, leading to the recovery of flowback and produced water. Flowback is the fluid returned to the surface after hydraulic fracturing has occurred, but before the well is placed into production. Produced water is the fluid returned to the surface after the well has been placed into production (for the purpose of producing gas). Flowback and produced water are collectively referred to as "hydraulic fracturing wastewater" and may contain chemicals injected as part of the hydraulic fracturing fluid, substances naturally occurring in the oil-or gas-producing formation, hydrocarbons, and potential reaction and degradation products. [(5)]

The wastewater is typically stored onsite in impoundment pits or tanks. [(5)] Estimates of the fraction of hydraulic fracturing wastewater recovered vary by geologic formation and range from 10% to 70% of the injected hydraulic fracturing fluid. For a hydraulic fracturing operation that uses 5 million gallons of hydraulic fracturing fluid, between 500,000 and 3.5 million gallons of fluid will be returned to the surface. [(5)]

The dramatic increase in oil and gas production using new "unconventional" technologies, including high volume hydraulic fracturing (HVHF) techniques in tight shales, presents new challenges to regulators trying to comprehend the wide ranging impacts and mitigate risks to environmental and human health. HVHF is just one step in the production of unconventional shale gas reservoirs. HVHF and associated risks are discussed throughout this report.

Renderings of various stages of HVHF are included as Appendix A. A schematic illustrating well casing and extraction methods is presented below.

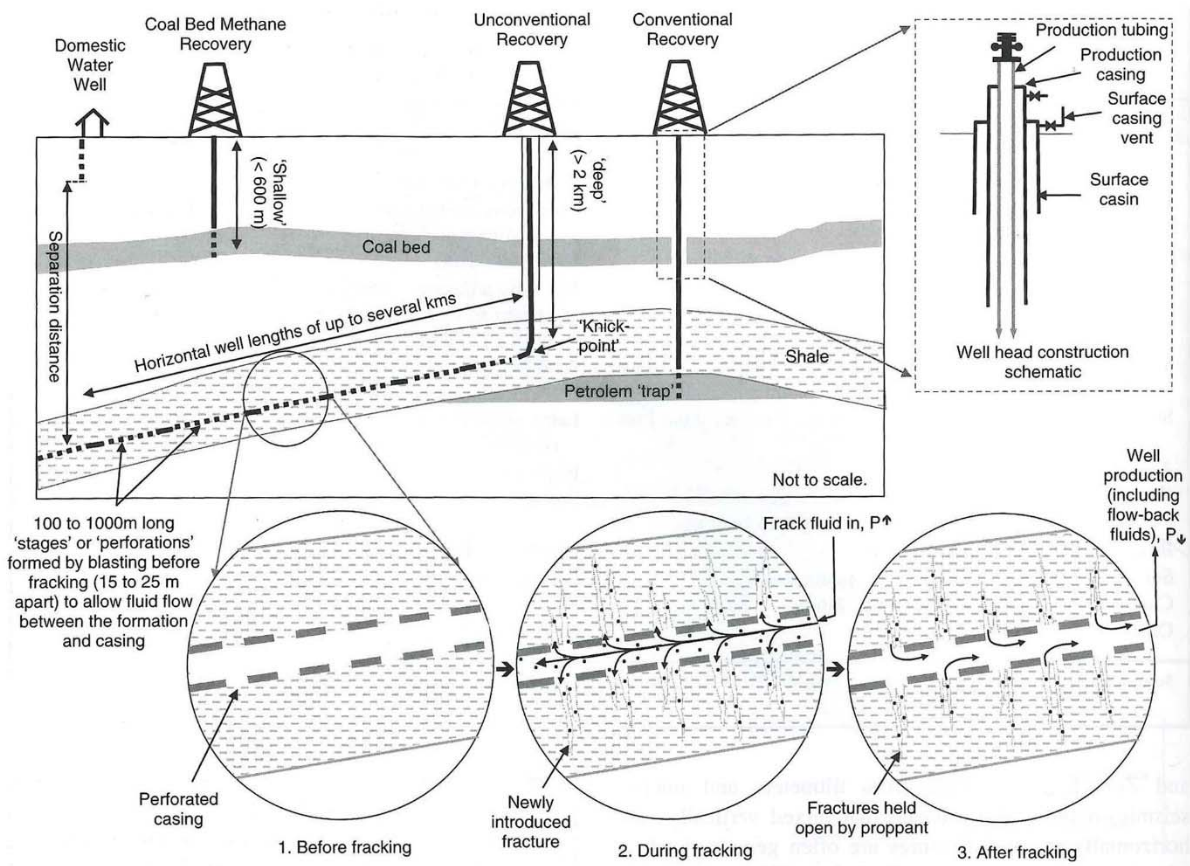


Figure 2. Schematic illustrating (i) the nature of conventional, coal-bed methane, and "unconventional" resource recovery, (ii) the hydraulic fracturing process; and (iii) the nature of surface and production casing (and associated borehole annulus cementing).

Source: Jackson, R.E. et al. (2013, July-August). Groundwater Protecttion and Unconventional Gas Extraction: The Critical Need for Field-Based Hydrogeological Research. *Groundwater, 51*, 488-510.

(2) Shale Plays in the Eastern U.S.

Several “shale plays” as referred to in the oil and gas industry exist in the U.S. The Marcellus Shale of the Appalachian Basin extends throughout eight eastern U.S. states including areas of New York, Pennsylvania, Ohio, West Virginia, Maryland, Kentucky, Tennessee and Virginia, and includes an area of 95,000 square miles. (4)

U.S. natural gas production, thought to be in terminal decline as recently as 2005, has exceeded its all-time 1973 peak. The U.S. Energy Information Administration (EIA) now projects domestic gas production to reach nearly 38 trillion cubic feet per year by 2040, which is 55% above 2013 levels. (7) The Marcellus play is now the largest and fastest growing shale gas play in the U.S. It is also the largest play in terms of areal extent, stretching from New York State to southern West Virginia and west to Ohio, although most production comes from Pennsylvania. As of mid-2014, over 10,700 wells have been drilled to date of which 7,006 were producing. Of these, more than 7,900 are in Pennsylvania, 5,302 of which were producing in mid-2014. There is a large backlog of drilled but not connected wells believed to be over two thousand in number. This is a function of the rate of drilling and the relative youth of the play; most of these wells will be connected over time as pipeline infrastructure catches up. (7)

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

The Utica Shale is a black shale that extends across the Appalachian Plateau from New York and Quebec, Canada, south to Tennessee. It covers approximately 28,500 square miles in New York and extends from the Adirondack Mountains to the southern tier and east to the Catskill front. The Utica Shale is exposed in outcrops along the southern and western Adirondack Mountains, and it dips gently south to depths of more than 9,000 feet in the southern tier of New York. [8]

(3) Vermont Geology

The Marcellus shale does not occur in Vermont. Shales correlative with the Utica Formation occur in the Stony Point and Iberville Formations in the Champlain Valley region of western Vermont. Detailed exploration and testing would be needed in order to determine subsurface structures, lithologies (rock types), unit thicknesses at depth, organic carbon content and whether or not natural gas is present as an economically viable resource. Preliminary total organic values of 0.59-1.47 and extremely low HI (hydrogen index) values were obtained by the USGS in 2010 from 8 shale samples in western Vermont (Lewan, pers. comm, 2014). The samples were interpreted as "burnt out" or over mature. Shales in the region were thickened structurally and deformed by ancient multiple fold and fault events resulting in subsurface complexity which is difficult to predict from mapping of surface features alone. An oil and gas test well drilled in Alburg in 1964 showed complex structure, stratigraphy which could not be ascertained and no gas was discovered [9]. Although it cannot be completely ruled out, the likelihood of natural shale gas resources in Vermont is slim (M. Gale, State Geologist, pers. comm.).

The geology of Vermont and the Champlain Valley is summarized in a 2011 report "*Vermont Bedrock and its Potential for Sequestration"* [9] submitted by the Vermont Geological Survey to the US Geological Survey (USGS) as part of the USGS assessment of the potential to sequester carbon dioxide. Carbon sequestration is a possible strategy to reduce greenhouse gas emissions and mitigate global climate change. The report includes a summary of Vermont's bedrock geology, a detailed discussion of the sedimentary rocks in the Champlain Valley and data from 6 oil and gas test wells drilled in northwestern Vermont from 1957-1984. The six test wells were drilled to depths of 2306' to 6968' and were looking for oil and gas in porous formations (versus tight shales). Refer to Appendix B for well locations. Five of the wells are interpreted to have penetrated the Cambro-Ordovician section of black shales, carbonates and Potsdam sandstone lithologies; the 6th well (Burnor well) penetrated the rift clastic section further to the east. For more information, a copy of the report can be found via the following link: http://www.anr.state.vt.us/dec/geo/pdfdocs/TechReports/CO2WithAppendixA.pdf

(4) Federal Background

Congress has power to regulate hydraulic fracturing activities under the Commerce Clause of the U.S. Constitution. EPA retains authority to address many issues related to HVHF 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. [10]

The oil and natural gas industry has exemptions or exclusions from key parts of at least 7 of the 15 major federal environmental laws, as outlined by the Sierra Club, designed to protect air and water from radioactive and hazardous chemicals:

1. The Safe Drinking Water Act (SDWA) was established to protect America's drinking water from being contaminated. However, the Energy Policy Act of 2005 -- also known as the "Halliburton Loophole" exempted fracking from SDWA oversight, leaving drinking water sources in the 34 oil-and-gas-producing states unprotected from the host of toxic chemicals used during fracking, effectively exempting the industry from being held accountable for its pollution.

Halliburton Loophole: The SDWA sets a framework for the Underground Injection Control (UIC) program to control the injection of wastes into ground water. US EPA and states implement the UIC program, which sets standards for safe waste injection practices and bans certain types of injection altogether. All of these programs help prevent the contamination of drinking water. As noted above, hydraulic fracturing for oil and gas is exempt per Section 322. Hydraulic Fracturing under the Energy Policy Act of 2005 where paragraph (1) of Section 1421(d)of the Safe Drinking Water Act (42 U.S.C 300h(d)is amended to read as follows: (1) UNDERGROUND INJECTION.—The term 'underground injection'—(A) means the subsurface emplacement of fluids by well injection; and (B) excludes— (i) the underground injection of natural gas for purposes of storage; and (ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities.

2. The Clean Air Act (CAA), adopted in 1970, is the comprehensive federal law that regulates air emissions from stationary and mobile pollution sources. The CAA exempts oil and gas wells from controlling toxic air emissions by preventing the aggregati
on of multiple sources of pollution -- for example, multiple wells on one well pad. This lack of aggregation allow multiple facilities to operate in a small area, in some cases emitting large quantities of air contaminants, while going largely unregulated by the CAA.

3. The Clean Water Act (CWA), enacted in 1972, establishes the basic structure for regulating discharges of pollutants into the waters of the United States. Exemptions granted in 1987, and amended during the 2005 Energy Policy Act, define sediment as a non-pollutant and exempt oil and gas construction activities from storm-water permitting, leaving streams unprotected from the sediment runoff caused by the construction and operation of well pads, pipelines, drill rigs, and other infrastructure.

4. The Resource Conservation and Recovery Act (RCRA) adopted in 1976, is the principal federal law that governs the disposal of solid and hazardous wastes. The law takes a cradle-to-grave approach to ensure that wastes are handled properly from the point of creation to transport to disposal. In 1980, Congress exempted oil field wastes (which include waste from natural gas production) from the RCRA and gave authority to states to regulate these wastes.

5. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as the Superfund law, makes companies liable for a spill or release of a hazardous substance into the environment. Included in the list of hazardous substances under CERCLA are benzene, toluene, ethylbenzene, and xylene (BTEX). CERCLA exempts these chemicals when they are found in crude oil or petroleum, which are both widely used in natural gas production. The definition of a hazardous substance under CERCLA also excludes natural gas, natural gas liquids, liquefied natural gas, and synthetic gas usable for fuel.

6. The National Environmental Policy Act (NEPA) established the broad national framework for protecting our environment. NEPA stipulates that the federal government must give proper consideration to potential environmental impacts before undertaking any major federal action. The Energy Policy Act of 2005 stripped NEPA's strong requirements for public involvement and environmental review of several oil-and-gas-related activities. Instead, the act stipulated that they should be analyzed and processed by the departments of Interior and Agriculture a process known as a "categorical exclusion," rather than the most comprehensive Environmental Assessment (EA) or Environmental Impact Statement (EIS) processes. In 2006 and 2007, the Bureau of Land Management (BLM) granted this exemption to about 25 percent of all oil and gas wells approved on public lands in the West.

7. The Toxic Release Inventory of EPCRA (TRI) was created by section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. It requires most industries to report significant releases of toxic substances to the EPA, which then aggregates and disseminates the information to the public. However, despite the use of toxic chemicals throughout production, oil and gas facilities are not required to report to the TRI.

B. How should hydraulic fracturing be regulated in the state?

With input from the Senate Natural Resources and Energy Committee, Vermont Statute 29 V.S.A. Chapter 14, was modified effective May 16, 2012, with the following: (a) No person may engage in hydraulic fracturing in the State (b) No person within the State may collect, store, or treat wastewater from hydraulic fracturing. Furthermore, the UIC Regulations under Chapter 11 of the Environmental Protection Rules were amended and became effective October 29, 2014. The amended Rules provide the following, prohibiting fracking in the State: (a) No person shall construct, operate, maintain, or convert any Class I, Class II, or Class III well. (c) No person shall construct, operate, maintain, modify, or convert a Class V well that receives waste from the location within a facility or business where the following occurs: (14) hydraulic fracturing used to extract natural gas or oil. The following report is submitted as requested by the Vermont Legislature in the event that hydraulic fracturing is reconsidered in the future.

The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. As such, no state agency, board or instrumentality is authorized to regulate hydraulic fracturing in the state.

(1) What state agency, board, or instrumentality should be authorized by the general assembly to regulate hydraulic fracturing in the state?

Generally speaking, despite Congress's power to regulate hydraulic fracturing activities under the Commerce Clause of the U.S. Constitution, regulation of the technology and of the oil and gas industry in general is largely left to the states. [1] Hydraulic fracturing for oil and gas production wells is typically addressed by state oil and gas boards or equivalent state natural resource agencies. In addition, states or EPA have authority under the Clean Water Act to regulate discharge of produced waters from hydraulic fracturing operations and the use of diesel fuel during hydraulic fracturing. State oil and gas boards or agencies may have additional regulations for hydraulic fracturing. The State of Vermont has in place the relevant boards and agencies necessary to regulate hydraulic fracturing in the State as summarized below.

Vermont Natural Gas and Oil Conservation Act and Natural Gas and Oil Resources Board

Vermont Statute 29 V.S.A. § 501 establishes the Vermont Natural Gas and Oil Conservation Act. The purpose of the Act is "the prevention of waste of oil and gas, the promotion of conservation, and the protection of correlative rights of owners are declared to be in the public interest".

The purposes of 29 V.S.A. are to:

(1) Encourage oil and gas exploration and production;

(2) Protect property rights and interests of all citizens;

(3) Prevent long-term harm to the environment and other resources that might occur through oil and gas activities;

(4) Protect correlative rights;

(5) Prevent undue waste of oil and gas;

(6) Promote greatest ultimate recovery of oil and gas, consistent with technology and economic conditions.

(c) This purpose requires the creation of a Vermont natural gas and oil resources board to administer and enforce the provisions of this chapter.

(d) Whenever the board exercises discretion and authority under this act, it shall do so only under the standards and purposes described in subsection (b) of this section. (Added 1981, No. 240 (Adj. Sess.), § 2, eff. April 28, 1982.)

The composition of the Natural Gas and Oil Resources Board is established via 29 V.S.A. § 504, and reads as follows:

(a) The Board shall consist of five members who shall be appointed by the Governor with the advice and consent of the Senate. Appointments shall be for a term of three years and, in the event of death or resignation, successors shall serve out the term of the deceased or resigned member. The terms of members initially appointed shall be set so that not more than two terms shall expire in the same year. Annually, in February after new appointments, the Governor shall designate a chair.

(b) In order for the board to function in the best interests of the people of the State, Board members should have a knowledge of one or more of the following: geology, engineering, law, State and local government, economic development, environmental protection, regional planning, agriculture or related fields of knowledge.

(c) A person in the employ of or holding any official relation to any company subject to the supervision of the Board, or engaged in the management of such company, or owning stock, bonds or other securities thereof, or who is, in any manner, connected with the operation of such company in this State, shall not be a member of the Board.

(d) No member of the Board shall participate in any action of the Board which involves himself or any person engaged in oil and gas development in which he or she has a financial interest.

(e) Each prospective appointee or member of the board shall have the affirmative duty to disclose any actual or potential conflicts of interest to the other members of the Board. (Added 1981, No. 240 (Adj. Sess.), § 2, eff. April 28, 1982.)

The Board has authority under 29 V.S.A. § 505

(a) For the purposes of this chapter the board shall have authority over all lands and over all oil and gas resources. The board shall prevent the waste of oil and gas, promote conservation, protect correlative rights, and otherwise administer and enforce this chapter. In the event of a conflict, the duty to prevent waste is paramount.

Current Board:

Board Member Name	Term Expires
Catherine Dimitruk	2/29/2016
Donald Marsh	2/28/2017
Aaron Melville	2/28/2012
Mary Skinner	2/28/2015
vacancy	2/28/2017

According to Mr. Marsh who has been on the Board for three years, the Board is inactive and has not convened since he has been on the board (Don Marsh, pers. comm.)

Act 250 and the Natural Resources Board

10 V.S.A. Conservation and Development Law Chapter 151 establishes Vermont's Act 250 Land Use law. "The Natural Resources Board (NRB) administers Act 250. Act 250 is intended to minimize the environmental impacts of development, by requiring that projects comply with the Act 250 Criteria. Act 250 permit applications are reviewed by the District Environmental Commissions, and are staffed by the District Coordinators. The District Coordinators also issue Jurisdictional Opinions on whether an Act 250 permit is required. In addition to administering the Act 250 program in the district offices, the NRB issues rules and policies related to Act 250, reviews requests to reconsider Jurisdictional Opinions, is responsible for enforcement of Act 250, and may participate as a party in appeals from Act 250 decisions at the Superior Court, Environmental Division.

There are nine Environmental Districts across the State. Each Act 250 application must meet 10 Criteria (described in detail in the next section).

Exploration for Oil and Gas and other earth resources are subject to Act 250 jurisdiction according to the following:

> § 6001. Definitions: (3) (A) "Development" means each of the following: (viii) The drilling of an oil and gas well;
>
> § 6086. Issuance of permit; conditions and criteria. (a) (1) (9) (as in Criteria 9 above):
>
> (D) Earth resources. A permit will be granted whenever it is demonstrated by the applicant, in addition to all other applicable criteria, that the development or subdivision of lands with high potential for extraction of mineral or earth resources, will not prevent or significantly interfere with the subsequent extraction or processing of the mineral or earth resources.

(E) Extraction of earth resources. A permit will be granted for the extraction or processing of mineral and earth resources, including fissionable source material:

(i) When it is demonstrated by the applicant that, in addition to all other applicable criteria, the extraction or processing operation and the disposal of waste will not have an unduly harmful impact upon the environment or surrounding land uses and development; and

(ii) Upon approval by the District Commission of a site rehabilitation plan that ensures that upon completion of the extracting or processing operation the site will be left by the applicant in a condition suited for an approved alternative use or development. A permit will not be granted for the recovery or extraction of mineral or earth resources from beneath natural water bodies or impoundments within the State, except that gravel, silt, and sediment may be removed pursuant to the rules of the Agency of Natural Resources, and natural gas and oil may be removed pursuant to the rules of the Natural Gas and Oil Resources Board.

Permits from the Agency of Natural Resources, Department of Environmental Conservation (ANR-DEC) (see below) are often required in the Act 250 process as presumptions of compliance with the appropriate criteria. In some cases final DEC permits are required for a complete Act 250 permit application. In addition, ANR and DEC staff make recommendations to the District Commissions based on technical evaluations of each application for impacts on natural resources such as air quality, soil erosion, water quality, wetlands and wildlife habitat. The ANR and DEC do not issue Act 250 permits. Only District Commissions and the NRB have authority to issue or deny Act 250 permits. (http://www.anr.state.vt.us/dec/permits.htm#act250)

Agency of Natural Resources

3 V.S.A. Chapter 51 establishes the Agency of Natural Resources (ANR). ANR includes, in part, the following: the Department of Fish and Wildlife; Department of Forests, Parks and Recreation; the Department of Environmental Conservation; the State Natural Resources Conservation Council; and, the Division of Geology and Mineral Resources. The Natural Resources Board is attached to the Agency for the purpose of receiving administrative support. The Agency provides representation on The Interstate Commission on the Lake Champlain Basin and The New England Interstate Water Pollution Control Commission.

The Vermont UIC Rules, were originally adopted in 1982, under the Environmental Protection Rules, Chapter 11, (formerly cited as Vermont Water Pollution Control Regulations, Subchapter 13).
The Vermont UIC Rules are implemented by the Secretary under the authority of 10 V.S.A. Chapter 47 and Part C of the SDWA. There are six classes, of injection wells, Classes I-VI. Five of these classes of injection wells involve generally very deep, high-tech wells used for the disposal of hazardous and radioactive wastes, enhancement of oil and gas and mineral recovery (Class II) or carbon sequestering. All but Class V wells are prohibited in Vermont. The Memorandum of Agreement between EPA Region I and the Vermont Agency of Environmental Conservation was signed by the EPA Regional Administrator on January 16, 1984.

The Vermont UIC Program has the following federal origins:

Title 40 Protection of the Environment
Chapter 1 – Environmental Protection Agency
Subchapter D – Water Programs
Part 147 State UIC Programs; Subpart Uu-Vermont
Section 147.23 State Administered Program.

The Vermont UIC Rules are administered through the ANR-DEC Drinking Water and Groundwater Protection Division's (DWGPD's), UIC Program. The protection of Underground Sources of Drinking Water (USDWs) is focused in the UIC program, which regulates the subsurface emplacement of fluid.

The Vermont UIC Rules are intended to:

(1) Protect the quality of groundwater in the State of Vermont by regulating the discharge of waste into injection wells;

(2) Assure that injection wells are designed, constructed, operated, maintained, converted, abandoned and closed in a manner that complies with the Groundwater Protection Rule and Strategy; and

(3) Protect the groundwater resources that are held in trust for the public.

UIC staff are charged with the responsibility of ensuring that state rules are being followed by the regulated community. Regulatory agencies (such as the Agency of Natural Resources and NRB) help accomplish this by conducting administrative and technical reviews of permit applications, witnessing field operations, performing field inspections, conducting meetings and hearings and, where necessary, taking formal enforcement action to achieve compliance.

Congress provided for exclusions to UIC authority (SDWA § 1421(d)), with the most recent language added via the Energy Policy Act of 2005:

"The term 'underground injection' –

(A) **means** the subsurface emplacement of fluids by well injection; and
(B) **excludes** –
(i) the underground injection of natural gas for purposes of storage; and
(ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities."

While the SDWA specifically excludes hydraulic fracturing from UIC regulation under SDWA § 1421 (d) (1), the use of diesel fuel during hydraulic fracturing is still regulated by the UIC program. Any service company that performs hydraulic fracturing using diesel fuel must receive prior authorization through the applicable UIC program.

In states with significant oil and gas activity, the UIC Class II program, which is exclusively related to that industry's activities-is often housed in the State's Oil and Gas Agency.

The Senate Natural Resources and Energy Committee through legislative action and the Agency of Natural Resources, through the UIC program, recently exercised its authority by enacting laws and rules prohibited hydraulic fracturing for oil and gas in the State of Vermont. The Underground Injection Control Regulations under Chapter 11 of the Environmental Protection Rules were recently amended and adopted by the Secretary. The revised Rules became effective October 29, 2014 and have the force of law

The following prohibitions pertaining to the potential for hydraulic fracturing for the purposes of oil and gas recovery were included in the UIC Rule Amendment under Chapter 11 of the Environmental Protection Rules:

Under Subchapter 3 Prohibitions, Section §11-301 Prohibitions

(a) No person shall construct, operate, maintain, or convert any Class I, Class II, or Class III well.

(c) No person shall construct, operate, maintain, modify, or convert a Class V well that receives waste from the location within a facility or business where the following occurs: (14) hydraulic fracturing used to extract natural gas or oil.

Class II Waste injection wells used for the injection of liquid wastes generated through hydraulic fracturing of oil and gas bearing formations are now prohibited in the State of Vermont.

In accordance with (c) above, Class V wells are prohibited at any site involved in hydraulic fracturing for oil and gas.

Prohibition by Vermont Statute

Vermont Statute 29 V.S.A. Chapter 14,

Sub-Chapter 1: General Provisions

§ 503 Definitions

(30) "Hydraulic fracturing" means the process of pumping a fluid into or under the surface of the ground in order to create fractures in rock for the purpose of the production or recovery of oil or gas. (Added 1981, No. 240 (Adj. Sess.), § 2, eff. April 28, 1982; amended 2011, No. 152 (Adj. Sess.), § 2, eff. May 16, 2012.)

Sub-Chapter 8: Hydraulic Fracturing For Oil or Gas Recovery

§ 571. Hydraulic fracturing; prohibition

(a) No person may engage in hydraulic fracturing in the State.
(b) No person within the State may collect, store, or treat wastewater from hydraulic fracturing. (Added 2011, No. 152 (Adj. Sess.), § 3, eff. May 16, 2012.)

(2) How should hydraulic fracturing be regulated in the state?

(a) How should hydraulic fracturing be permitted?

The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. As such, there is no permitting of HVHF or associated activities for oil and gas in the State of Vermont.

In the event that the Vermont Legislature decides to allow hydraulic fracturing at some time in the future, the Natural Gas and Oil Resources Board would be reactivated to issue permits in conjunction with the Natural Resources Board/Act 250, the Agency of Natural Resources and local municipalities

Permitting would be performed in accordance with authorities described above in accordance to the specific tasks generally outlined below. Additional tools will be developed to ensure appropriate efficiency for State staff and developers, to ensure effectiveness of protecting the environment and maximizing data collection and sharing of information.

Natural Gas and Oil Resources Board (NGORB)

In general, the NGORB would: oversee the tasks association with oil and gas exploration including all downhole drilling activities; assure proper maintenance and handling of equipment; and ensure legal instruments pertaining to lease and mineral rights are confirmed. Generally speaking, in accordance with its authorities under 29 V.S.A. § 505 the NGORB authority, the board may:

(1) Require identification of ownership of oil and gas wells, producing leases, tanks, processing plants, structures, and facilities for the transportation or refining of oil and gas;

(2) Require the making and filing of well logs, directional surveys, and reports on well location, drilling and production; provided that all such records marked "confidential" shall be kept confidential for two years after their filing, unless the owner gives written permission to release them at an earlier date; provided, however, that the state geologist is authorized access to this information. The board may provide by rule for extension of the period of confidentiality for an additional period of one year upon written request of the owner and a showing of special circumstances requiring an extension;

(3) Require the drilling, casing, installation of proper equipment and facilities, operating, and plugging of wells in such manner as to prevent:

(A) The escape of oil or gas out of one reservoir into another,

(B) The detrimental intrusion of water into an oil or gas reservoir where that is avoidable by efficient operations,

(C) The pollution of fresh water supplies by oil, gas or salt water, or other substances,

(D) Blowouts, cave-ins, seepages, and fires;

(4) Require the testing of wells used in connection with the production of oil and gas including, but not limited to, production, injection, and disposal wells;

(5) require the licensing of oil and gas well drillers and the furnishing of a reasonable performance bond or other good and sufficient surety, conditioned for the performance of the duty to plug and restore the drilling site of each dry or abandoned well, and to repair each well causing waste or pollution if repair will prevent the waste or pollution;

(6) Require that production from wells be separated into gaseous and liquid hydrocarbons, and that each be measured by means and upon standards that may be prescribed by the board;

(7) Require that wells be operated at efficient gas-oil or water-oil ratios or that production be limited from wells with inefficient gas-oil or water-oil ratios;

(8) Require certificates of clearance in connection with the transportation or delivery of oil, gas, or product;

(9) Require the metering or other measuring of oil, gas, or product;

(10) Require that every person who produces, sells, purchases, acquires, stores, transports, refines, or processes oil or gas in this state keep complete and accurate records of their quantities, which records shall be available for examination by the board or its agents at all reasonable times;

(11) Require the filing of reports, plats, and other data related to matters within the board's jurisdiction;

(12) Regulate the drilling, testing, equipping, completing, operating, producing, and plugging of wells, and all other operations for the production of oil or gas;

(13) Regulate the stimulation and treatment of wells;

(14) Regulate the spacing or locating of wells;

(15) Regulate operations to increase ultimate recovery, such as cycling of gas, the maintenance of pressure, and the introduction of gas, water or other substances into a reservoir;

(16) Regulate the disposal of salt water and oil field wastes;

(17) Determine the amount of oil or gas that may be produced without waste from any unit, reservoir, or field, and allocate the allowed production to and among the wells in such fields or reservoirs;

(18) Permit by rule or order the flaring of gas produced from an oil well, pending the time when, with reasonable diligence, the gas can be sold or otherwise utilized on terms that are just and reasonable, if such flaring is in the public interest;

(19) Identify reservoirs and classify or reclassify them as oil or gas reservoirs, and classify or reclassify wells as oil or gas wells;

(20) Adopt rules and make and enforce orders reasonably necessary to prevent waste, to protect correlative rights, to govern the practice and procedure before the board and otherwise administer this chapter;

(21) Implement state responsibility under the National Gas Policy Act of 1978 for determining the statutory maximum lawful price for sales of natural gas;

(22) The board shall have no authority over sales of gasoline and related products covered by Title 9, chapter 109, nor any authority over petroleum inventory reporting covered by Title 9, chapter 110. (Added 1981, No. 240 (Adj. Sess.), § 2, eff. April 28, 1982.).

Act 250 and the Natural Resources Board

Applicants will need to supply sufficient information for the District Commission to make findings on the ten environmental criteria. In so doing, certifications and/or approvals from other agencies and departments, utilities, regional planning commissions and local government may be necessary. The following criteria are listed below.

1. Will not result in undue water or air pollution. Included are the following considerations: (A) Headwaters; (B) Waste disposal (including wastewater and stormwater); (C) Water Conservation; (D) Floodways; (E) Streams; (F) Shorelines; and (G) Wetlands.
2. Has sufficient water available for the needs of the subdivision or development.
3. Will not unreasonably burden any existing water supply.
4. Will not cause unreasonable soil erosion or affect the capacity of the land to hold water.
5. Will not cause unreasonably dangerous or congested conditions with respect to highways or other means of transportation.
6. Will not create an unreasonable burden on the educational facilities of the municipality.
7. Will not create an unreasonable burden on the municipality in providing governmental services.
8. Will not have an undue adverse effect on aesthetics, scenic beauty, historic sites or natural areas, and 8(A) will not imperil necessary wildlife habitat or endangered species in the immediate area.
9. Conforms with the Capability and Development Plan which includes the following considerations: (A) The impact the project will have on the growth of the town or region: (B) Primary agricultural soils; (C) Productive forest soils; (D) Earth resources; (E) Extraction of earth resources; (F) Energy conservation; (G) Private utility services; (H) Costs of scattered developments; (J) Public utility services; (K) Development affecting public investments; and (L) Rural growth areas.
10. Is in conformance with any local or regional plan or capital facilities program.

There are several divisions within the ANR-DEC that may need to review and issue permits in order for the applicant to receive an Act 250 Land Use Permit or a Drilling Permit from the NGORB.

Concerns associated with hydraulic fracturing activities are directly related to and would require review under each Act 250 Criteria. For example, activities include:

1. Toxic and greenhouse gas air emissions from vehicle use transporting millions of gallons of water and wastewater, methane gas release during drilling, extraction and transport of gas, diesel equipment operation; chemical and fuel storage and accidental spills; underground injection of hazardous chemicals, well construction to prevent contaminant migration, wastewater disposal; and, erosion control.
2. Groundwater and surface water impacts related to withdrawing millions of gallons of water.
3. Water supply well interference due to groundwater withdrawals and potential contaminant migration from the well bore.
4. Sediment runoff from clearing during well pad construction.
5. Traffic generated from increases in population and drilling and hydrofracking activities including thousands of oversized and/or heavy vehicle trips to transport water, chemicals and equipment.
6. Increased transient and permanent population increases resulting from the influx of actual, related and supporting jobs.
7. As population increases due to job growth and opportunities, demands for governmental service are expected to increase.
8. Well pad placement and construction, often several acres, can result in adverse impacts on aesthetics, scenic beauty, historic sites, natural areas, wild life habitat and endangered species if present. Well pads may involve several acres of land
9. Permanent and temporary population impacts would be reviewed. Well pad placement and roads may be located in areas of primary agricultural soils, result in the fragmentation of productive forest soils, increase potential for scattered development intended to accommodate new or temporary population growth including rural areas. Significant truck volume and weight increases would impact public roads and infrastructure.
10. Conformance of drilling activities to the town and regional plans would be reviewed.

Adverse impacts are likely to be identified under each Criteria and would require careful review and coordination among State Agencies/Departments and Divisions to cost effectively mitigate impacts.

ANR-DEC

Supporting permits issued by the ANR that may be required if hydraulic fracturing for oil and gas were to take place in the State of Vermont.

The Air Quality & Climate Division (AQCD) implements state and federal Clean Air Acts. As part of this implementation, the AQCD monitors air quality and air pollution sources, proposes regulations to improve existing air quality, ensures compliance with the regulations, and issues permits to control pollution from sources of air contaminants across the state. http://www.anr.state.vt.us/air/index.htm

The Waste Management & Prevention Division oversees the use, treatment and handling of hazardous and solid wastes. The Division performs emergency response for hazardous materials spills, issues permits for federal and state programs regulating hazardous wastes, solid wastes, and underground storage tanks, and manages cleanup at hazardous sites under state and federal authorities, including the

RCRA and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA, also known as Superfund). http://www.anr.state.vt.us/dec/wastediv/index.htm

The Watershed Management Division's primary mission is to protect, maintain, enhance and restore the quality of Vermont's surface water resources. Inherent in this effort is the support of both healthy ecosystems and public uses in and on more than: 808 lakes and ponds; 7,100 miles of rivers and streams; and, 300,000 acres of wetlands that exist within the State of Vermont. http://www.watershedmanagement.vt.gov

The Drinking Water and Groundwater Protection Division The Division includes two applicable programs including the Underground Injection Control Program and the Groundwater Withdrawal (water) Program. The UIC Program reviews permit applications, makes jurisdiction determinations and issues permits for discharging non-sanitary waste into an opening in the ground.

Class II injection wells are used for the injection of liquid wastes ("flowback" and/or "produced water") generated from oil and gas drilling activities. Class II injection wells are also used if diesel fuel is used in hydraulic fracturing. All of these activities, including installation of Class II wells are currently prohibited so the UIC Rules would need to be amended to allow these wells in Vermont. Assuming that was to occur, an UIC permit would be required for these oil and gas drilling activities utilizing injection wells.

http://www.drinkingwater.vt.gov/

Technical Considerations

The Groundwater Protection Council conducted a five year study following 29 Oil and Gas States and the development of regulatory requirements pertaining to oil and gas drilling. The first study was conducted in 2009 and a recent study was release in 2014. [3] Excerpts of study highlights pertaining to permitting and regulations are included below.

Permitting Trends: (3)

Several elements of permitting have been adopted by a large number of states since 2009, including:

- Public notice required prior to issuance
- Permits denied or delayed if applicant is not in compliance
- Permits can be revoked for non-compliance

One emerging aspect of permitting is requiring a review of the geology around a wellbore to evaluate potential subsurface fluid pathways that could interfere with full containment during completion operations (sometimes referred to as "Area of Review").

More states are asking operators to provide analysis of stratigraphic confinement when well stimulation occurs close to a protected water zone or in uncertain geology. In most cases, when thousands of vertical feet separate the stimulated area and protected water zones, this analysis can be brief and serves an informational purpose. In the cases where stratigraphic containment is in doubt, such an analysis decreases the risk of protected water contamination when state rules also require appropriate operational modifications."

Formation Treatment/Stimulation/Fracturing (3)

Several major trends have emerged in this area over the past four years. A growing number of states are now directly regulating the practice of hydraulic fracturing, focused especially on disclosure of chemicals used in the practice, public and regulator notice of hydraulic fracturing activity prior to commencement, and monitoring and reporting of pressures during hydraulic fracturing. Other emerging trends include requirements for baseline water testing prior to, and monitoring following, hydraulic fracturing treatment; water sourcing reporting; and cement evaluation reporting. Other trends have emerged slowly and consideration might be given to future use. One trend is requiring mechanical integrity testing prior to hydraulic fracturing treatment. Another is requiring that hydraulic fracturing be suspended upon discovery of a loss of mechanical or formation integrity. The existence of mechanical integrity means that materials within the well are isolated from the formation and protected water, while the lack of mechanical integrity means there is a risk of undesirable communication between well fluids and the formation or protected water.

Recommendations:

- Mechanical Integrity Testing requirements prior to well stimulation
- Monitoring and reporting requirements during well stimulation, and suspension of well stimulation when mechanical or formation integrity is compromised

Well Integrity (3)

Proper well integrity is essential to protecting groundwater during construction, completion, and production. In recent years, key states have engaged in major revisions to their well integrity programs. Highlights of these revisions include:

- Increased protection of groundwater through enhanced cementing requirements
- Increased agency attention to the depths of groundwater when reviewing permits
- States that address intermediate casing are providing more detailed specifications, like cementing requirements
- More states are providing casing standards
- More states are requiring corrective actions when there's evidence of cement failure
- More states are requiring the use of cement evaluation logs under specifically defined circumstances
- More states are requiring notification prior to casing and cementing

None of the above policies are pursued universally. Several specific well integrity policies merit consideration including:

- Comprehensive well integrity testing during construction, especially Formation Integrity Testing(or "shoe" testing) prior to drill out
- Centralization standards for production/long string
- Isolation of flow zones capable of over-pressurizing an annulus and corrosive zones
- Providing standards for reconditioned casing
- Specifying mix-water quality standards and requirements for free water content in cement

Temporary Abandonment (3)

Most states allow operators to temporarily abandon wells following completion. Operators use this status for a variety of purposes, from delaying production until economically advantageous to delaying timely plugging of unproductive wells. The first use is to be encouraged while the latter use is to be discouraged. Recognizing this, state regulators are increasingly imposing stringent time limits on temporary abandonment status, while regularly renewing TA status under specific circumstances.

Well Plugging (3)

A properly plugged well will permanently protect groundwater and other natural resources surrounding the well bore. While plugging principles have been well established or decades, there are some notable trends in this area:

- More states are allowing operators to submit cement tickets in lieu of witnessing.
- More states are specifying the method (e.g., pump and plug or "displacement") of plugging.
- States are requiring more detailed reporting on plugging

Recommendations:

- Witnessing plugging operations in lieu of allowing the submission of cement tickets to satisfy reporting requirements
- Cement placement across all protected water zones

Storage in Pits (3)

Various trends emerged regarding storage in pits. The number of states with competency standards for liners increased significantly, along with the number of states with a freeboard requirement. In addition, more states are specifying duration of use. Finally, several states have added requirements related to pit closure, including prior authorization, landowner notice, and soil sampling. There is a growing trend toward the use of modular, site assembled containment structures, sometimes referred to as "above-ground pits." Along with greater use, the storage capacity of these units is also increasing. Some states are in various stages of developing regulations to address the design, construction, and operation of modular storage units. Significant environmental risks are associated with modular storage facilities if they are not properly designed, constructed, and maintained given that failure will typically be of catastrophic nature with an instantaneous and total loss of containment.

Recommendations

- Permitting or authorization based on characteristics of the fluids stored
- Specific design, construction, and operation requirements including liners, freeboard, leak detection, duration of use, and operator inspection and maintenance
- Siting restrictions taking into consideration surrounding and use, proximity to drinking water sources, 100-year flood plain boundary, and separation from groundwater (confined and unconfined)
- Closure specifications including disposition of fluids, solids, and liners from the pit, and site restoration

Storage in Tanks (3)

Fluid storage in above-ground, enclosed tanks is increasing. Currently, with the exception of secondary containment provisions, most states do not specify tank design, siting, or operation requirements.

Recommendations:

- Permitting or authorization based on the characteristics of the fluids being stored

- Specifications that address design, construction, and operation of tanks, including tank materials, overfill prevention, spill containment, leak detection, and operator inspection, maintenance and record keeping
- Siting evaluation taking into consideration surrounding land use, proximity to drinking water sources, and 100-year flood plain boundaries
- Closure specifications including disposition of fluids and solids, tank removal and disposition, and site restoration

Transportation of Produced Water for Disposal (3)

The most common form of transportation of produced water is by truck. Although other transportation methods are in use, the focus of this regulatory evaluation was on produced water transporters and the results of this evaluation indicated that fewer than half of the oil and gas agencies surveyed required transporters to be permitted or required the recording of the volume of produced water transported off-lease.

Recommendations:

- Permitting or licensing of produced water transporters and the recording of the volume of produced water transported off-site
- Use of Memorandum of Understanding (MOU)/Memorandum of Agreement (MOA) between oil and gas agency and other state agencies where the oil and gas agency does not directly regulate transportation of produced water

Produced Water Recycling and Reuse (3)

Produced water recycling and reuse was a newly added element for the 2013 review. Therefore, there are no quantitative trends to specify. However, the data currently indicate that oil and gas agencies generally haven not yet addressed this topic. While water reuse and recycling could have several environmental advantages, care should be taken to identify and address environmental issues inherent to these processes.

Recommendations:

- Chemical characterization and management of side streams
- Regulation of use of produced water for purposes other than well stimulation
- Design, construction, operation, and removal standards for recycled water pipelines
- Use of MOU/MOA between oil and gas agency and other state agencies where the oil and gas agency does not directly regulate water recycling and reuse should be taken to identify and address environmental issues inherent to these processes.

Exempt Waste Disposal (3)

RCRA Subtitle C exempt waste disposal is widely regulated, with most oil and gas agencies addressing one or more elements reviewed, including on-site and off-site disposal of drill cuttings and application of produced water, waste oil, and/or tank bottoms to roads and lands.

Recommendations:

- Manifests for off-site disposal where appropriate

Spill Response (3)

The vast majority of states have regulations related to spill response that include agency notification on spills and on-site spill remediation. A smaller number of states specify a clean-up standard for spills. Recommendations:

- Clean-up standards should be established that are relative to the characteristics of the material spilled
- and impacted media

Water Sampling and Analysis (3)

Sampling and analysis of water resources potentially impacted by the oil and gas well drilling, completion, and operation activities is an issue that is definitely a topic of discussion and debate and in a number of states already incorporated into regulatory requirements. In states where water sampling and analysis is required, differences exist in a number of details including the following

- Radius from well site in which sampling will be performed;
- Number of required sampling locations and rationale for selecting these locations;

(b) Where and how should hydraulic fracturing be sited?

The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. As such, HVHF or associated activities for oil and gas shall not be sited in the State of Vermont.

Furthermore, the most favorable geologic setting for an oil and gas well is where oil and gas is found. The Marcellus shale does not occur in Vermont. Shales correlative with the Utica Formation gas-bearing shale occur in the Champlain Valley region of western Vermont. Detailed exploration and testing would be needed in order to determine subsurface structures, lithologies (rock types), unit thicknesses at depth, organic carbon content and whether or not natural gas is present as an economically viable resource. An oil and gas test well drilled in Alburg in 1964 showed complex structure, stratigraphy which could not be ascertained and no gas was discovered [(9)]. Although it cannot be completely ruled out, the likelihood of natural shale gas resources in Vermont is slim (M. Gale, State Geologist, pers. comm.).

Lake Champlain is a valued natural resource and area in Vermont which serves as a surface water drinking water supply for numerous communities and is a major recreation and tourism destination. The Lake Champlain Basin would not be a suitable location for oil and gas exploration and extraction activities including HVHF. Though no formal analysis has been performed, the anticipated environmental and economic impacts of performing such activities would be significant.

If the Vermont legislature were to allow HVHF in the future and economically viable resources were identified, Vermont's various environmental rules and regulations incorporate setbacks from potential sources of contamination to sensitive receptors such as water supplies, source water and groundwater protection areas, flood plains, streams and dwellings. The setbacks would be modified to accommodate the scale of HVHF. Suitable separation of the gas formation from any USDW is required and a thorough review of the subsurface should be conducted prior selecting and permitting a site. Horizontal well drilling has the advantage of extending beneath a sensitive area while at a more remote location.

A location where there is favorable infrastructure would include highway or rail access to support transport of many tons of supplies required. An adequate water supply is necessary to produce several million gallons of water over the course of a few days. Adequate area must be available for storing equipment and waste fluids generated during and after fracking.

Local zoning districts should consider schools and residential neighborhoods, socioeconomic impacts and environmental justice factors. HVHF operations should not be permitted on certain state lands because it is inconsistent with the purposes likely intended for those lands such as maintaining habitats.

(c) How should waste from the hydraulic fracturing be disposed?

The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. Class II Waste injection wells are used for the injection of liquid wastes generated through hydraulic fracturing of oil and gas bearing formations and are also prohibited in the State of Vermont. As such, waste from HVHF or associated activities shall not be generated or disposed in the State of Vermont.

Generally speaking, sources of wastes generated from high volume hydraulic fracturing for oil and gas drilling activities include wastewater (from flow back, production water and natural formation water), sludge from holding pits and tank bottoms and plastic liners from holding ponds. The volumes of water being managed have increased substantially with horizontal drilling and multi-staged hydraulic fracturing. (3)

Produced water is typically more saline than fresh water with total dissolved solids (TDS) contents ranging from less than 1,000 parts per million (ppm) TDS (some coalbed methane zones) to over 200,000 ppm TDS (deep oil and gas zones). For comparison purposes, seawater contains about 35,000 ppm TDS. In addition to TDS, produced water may contain other constituents including organic compounds, metals, salts, various cations and anions, and naturally occurring radioactive material (NORM). (3)

New York State proposed to require, as a permit condition, that the permittee demonstrate that it has an acceptable method to treat or otherwise legally dispose of wastewater associated with flowback and production water prior to the issuance of the drilling permit. Disposal and treatment options include publicly owned treatment works, privately owned high volume hydraulic fracturing wastewater treatment and/or reuse facilities, deep-well injection, and out of state disposal.(8)

Additional excerpts from the Groundwater Protection Council study of oil and gas state's trends regarding waste storage and disposal are included below.

Storage in pits

Although steel tanks and other above ground containment systems are becoming more prevalent, excavated pits are still the most common means of storing fluids during drilling and well operations. Pits are used for storage of produced water, for emergency overflow, temporary storage of oil, burn-off of waste oil, and temporary storage of well completion and treatment fluids. (3)

The three most common types of pits are:

- Drilling pits are used to store the fluids used during the drilling process. These fluids are usually made up of fresh water and bentonite clay. However, in some locations, oil-based and saltwater based muds are still used due to specific drilling and formation conditions. Pit liners are normally not used in cases where drilling mud is primarily fresh water, but are usually required for other types of drilling fluid.

- Emergency pits are constructed to capture spills and leaks. They are usually required to be kept dry except during an emergency and are not usually lined.

- Produced water storage pits are the largest type of pit and are used to store water that comes to the surface as part of the oil and gas production process. They are often associated with a Class II UIC disposal or enhanced recovery well. As of 2013, 22 of the 29 study states followed had competency standards for liners associated with these types of pits.[3]

Once a pit is no longer needed at the site, or its use is no longer authorized, it must be closed in a manner that will prevent pit contents and other materials from contaminating the soil or water. In drilling pits where fresh water and clay were used, the liquids are removed for proper disposal and residuals in the pit are buried in the pit. Where other types of drilling fluids were used, the fluids must be removed for proper disposal and the remaining residual solids must be removed from the pit and either bio-remediated on-site or removed and transported to a special waste landfill. [3]

For pits with artificial liners, the typical procedure is to drain the pit and remove the liner, or drain the pit, shred the liner, and bury it within the pit boundaries. Potential adverse impacts to agricultural operations may result if materials are buried at too shallow a depth or work their way back up to the surface. [10] In either case, the removed fluids must be disposed of properly. In some states, the operator must file a pit closure report detailing the steps taken to close the pit and dispose of the contents. [3]

*Storage in **Tanks***

A group of tanks used to store oil and produced water is often referred to as a "tank battery." Where water is not co-produced with oil, the tank battery typically consists of one or more oil storage tanks. However, when saltwater is part of the production fluid stream, the tank battery also usually includes a vertical gravity oil/water separator, sometimes called a "gun barrel" and one or more water tanks for the storage of saltwater that has been separated from the produced oil/ water stream. In some cases, additional tanks such as heater treaters, which use heat to break down the oil/water emulsion, are also present. Unlike pits, tanks provide a closed system for fluid storage. [3]

After separation, the oil and water are stored in separate collection tanks. These tanks are typically made of steel or fiberglass, although older tanks may have been made of concrete or even wood. Management of fluid flow through the tank system involves many simultaneous processes that must remain in balance for the system to work properly. A properly constructed and maintained tank battery can last decades. It is important that it is maintained over the life of the system so that leaks, spills and tank failures do not occur. As of 2013, 14 states required routine tank maintenance. [3]

After a tank has reached the end of its useful life, it must be removed from the site so that it does not pose an environmental or safety hazard. Steel tanks are most often re-used or cut up and sold for scrap while fiberglass tanks are re-used or cut up and disposed of in landfills. [3]

Removal of the tanks often leaves behind some contaminated soil at the tank battery site. If this soil is highly contaminated, it may have to be removed and disposed of properly, usually by internment in either a sanitary or special waste landfill depending on the level and nature of the contamination. In some cases, the soil is capable of being remediated on-site using procedures similar to those used for oil and saltwater spills. This may include either natural attenuation or active bio-remediation using disking of the soils and the addition of nutrients, lime and fresh water. The remediation methods allowed and the final remediation level required are determined by each state regulatory agency. (3)

Produced Water Disposal Options

In 1974, Congress passed the SDWA which required the U.S. EPA to develop minimum federal requirements for injection practices. EPA established a number of injection well classes including Class II injection wells, which are designed to accept oil and gas RCRA Subtitle C exempt waste, including produced water. Regulations adopted pursuant to the SDWA are administered either by EPA or state and tribal partners. The goal of the UIC program is the effective isolation of injected fluids from USDWs.

The vast majority of produced water is re-injected underground through an injection well that is permitted under the UIC program. According to EPA, there are approximately 168,000 Class II injection wells are located in 31 states. (3)

A primary environmental consideration with respect to disposal wells is the potential for movement of injected fluids into or between potential underground sources of drinking water. The potential for significant adverse environmental impacts from any proposal to inject flowback water from high volume hydraulic fracturing into a disposal well should be reviewed on a site-specific basis with consideration to local geology (including faults and seismicity), hydrogeology, nearby wellbores or other potential conduits for fluid migration and other pertinent site-specific factors. (8)

Another potential option for disposal of produced water includes treatment at a permitted facility capable of removing the constituents of concern to levels that meet permitted discharge standards. This potentially includes transport to and treatment at Publicly Owned Treatment Works (POTW) or Certified Water Technologists (CWTs). A facility that discharges treated water into waters of the United States must have a National Pollutant Discharge Elimination System (NPDES) permit. For a POTW to accept a waste stream for treatment, the facility must show that the accepted waste will not interfere with the treatment process or pass through the facility untreated. Since POTWs are typically not designed to treat fluids with constituents found in produced water (e.g., high TDS concentrations, hydrocarbons, etc.), problems have occurred as a result of produced water being sent to POTWs including impacts to the treatment process or the discharge of constituents at levels detrimental to the receiving water body. The potential for inhibition of biological activity and sludge settling and the potential for radionuclide concentration in the sludge impacts sludge disposal options. (3) (8)

Properly designed CWTs are an option for treating produced water to levels allowing for reuse in subsequent well completions and even potentially for discharge to a surface water body. In the latter case, the NPDES permitting process is critical in determining appropriate discharge standards. Although a few CWTs have been issued a NPDES permit that allows for the option of discharge to a surface water body, it is currently not a common practice. With the practice of recycling or reusing produced water, some form of treatment is likely needed. Environmental risks associated with this activity include the disposal of the produced water effluent stream when it is not fully utilized in other well completions and the disposal of waste streams generated as a result of the treatment process.(3)

The disposal of flowback water could cause a significant adverse impact if the wastewater was not properly treated prior to disposal. Residual fracturing chemicals and naturally-occurring constituents from the rock formation could be present in flowback water and could result in treatment, sludge disposal, and receiving-water impacts. Salts and dissolved solids may not be sufficiently treated by municipal biological treatment and/or other treatment technologies which are not designed to remove pollutants of this nature. (8)

Wastewater generated by high-volume hydraulic fracturing would be able to be treated and disposed of to the extent that available capacity exists. Should wastewater be generated in volumes exceeding available capacity within the State, either the wastewater would have to be transported and disposed of at facilities outside of the State, or additional treatment facilities would have to be constructed. (8)

Potential impacts that may result from insufficient wastewater treatment capacity would include storage of wastewater and associated potential for leaks or spillage, illegal discharge of wastewater to the ground surface or directly to waters of the State, and increased truck traffic resulting from transport of wastewater to out of state treatment and disposal facilities. (8)

Over the past few years, fluid recycling and reuse has become more prevalent in the oil and gas industry. Not only does fluid recycling and reuse lower disposal costs but it also lowers the amount of new water that must be obtained to conduct well drilling and completing operations, and decreases the overall amount of fluid requiring disposal. A primary factor in the increased use of fluid recycling has been the large volume of water that is typically necessary to conduct multi-staged hydraulic fracturing operations in horizontal wells. As the volumes of fluid needed to conduct fracturing operations dramatically increased and new shale gas plays were developed, the ability to acquire water of suitable quality to conduct these operations became more problematic. Water usage depends on many factors including the shale involved, lateral length, and fracture design. For example, water usage in the Marcellus in Pennsylvania has been recorded to range from 2 to 4 million gallons per fractured well, while water usage in the Eagle Ford can range from 3 to 16 million gallons. Drought conditions in some regions of the country such as the southwest added to the difficulties of acquiring new water and made the use of recycling a viable alternative. In some cases, regulatory authorities such as the Susquehanna and Delaware River Basin Commissions became involved in the process of authorizing water use for hydraulic fracturing, creating a new regulatory hurdle and making fluid recycling even more attractive. In Pennsylvania, the lack of nearby Class II disposal wells for injecting flowback water and associated transportation costs to injection wells in neighboring states has incentivized development of recycling and reuse technology. (3)

With the advent of fluid recycling, a whole new set of challenges is arising. Larger volumes of fluids have to be managed on-site, treatment systems have to be constructed and maintained, fluid treatment residuals and by-products have to be disposed of, and new piping and transport systems between the wells and the treatment facilities have to be built. In some states, such as Texas, new regulations have been developed to regulate and facilitate the practice of oilfield recycling. These regulations address storage in pits, disposal methods, management of waste haulers, and the use of commercial versus non-commercial facilities for recycling. Other states, such as Ohio, have passed legislation requiring entities to have a permit before they can store, treat, process or recycle produced water, and authorizing the chief to adopt rules for the construction and operation of such facilities. (3)

On-site treatment and reuse of fluids using smaller portable water treatment systems is also becoming popular in more rural areas. These systems work well for small volumes of fluids (dependent on the level of treatment required) and are usually fully self-contained so that treatment by-products are kept within the unit until their proper disposal can be accomplished. (3)

Exempt waste disposal – drill cuttings and tank bottoms
Wastes such as drill cuttings and tank bottoms typically require a different disposal strategy than produced water. While some wastes, such as drill cuttings, can be disposed of using underground injection, the primary disposal methods for such wastes may include onsite burial, off-site transport and burial in solid waste landfills, reuse for road base material or dust suppression, or bio-remediation using land-farming techniques. However, some wastes may contain metals and other constituents at concentrations that make their reuse or on-site remediation problematic. The determination as to whether a waste is RCRA Subtitle C exempt is based on several criteria. However, with respect to oil and gas wastes the most commonly used rule of thumb is if a waste is "intrinsically derived from primary field operations associated with the exploration, development or production of crude oil and natural gas" it is typically considered Subtitle C exempt. In most cases, such wastes retain their exempt status. However, where an exempt waste is mixed with a listed hazardous waste, the resulting mixture is no longer exempt, and becomes subject to the RCRA Subtitle C provisions. Additionally, where an exempt waste is mixed with another, non-exempt hazardous characteristic waste, and the resulting mixture exhibits hazardous characteristics, the mixture is no longer exempt and becomes subject to the RCRA Subtitle C provisions. (3)

Surface management and land application of wastes is regulated in 23 states, either through direct control by the oil and gas agency or another state environmental agency. For example, the Wyoming Oil and Gas Commission regulates the application of waste to land if the application occurs on a lease. However, off the lease, the same process is regulated by the Wyoming Department of Environmental Quality. (3)

Road spreading of some exploration and production (E&P) waste is one method of on-site management that is commonly allowed in multiple states. This technique is typically limited to the application of drilling wastes such as cuttings and tank bottoms, which are primarily sand but may contain up to 19% oil by volume. One concern raised by the road application of waste is the potential contamination of surface water sources due to dispersion of these wastes into roadside ditches. (3)

The total volume of drill cuttings produced from drilling a horizontal well may be about 40% greater than that for a conventional, vertical well. For multi-well pads, cuttings volume would be multiplied by the number of wells on the pad. The potential water resources impact associated with the greater volume of drill cuttings from multiple horizontal well drilling operations would arise from the retention of cuttings during drilling, necessitating a larger reserve pit that may be present for a longer period of time, unless the cuttings are directed into tanks as part of a closed loop tank system. (8)

Privately owned facilities built specifically for the reuse and/or treatment and disposal of industrial wastewater from high-volume hydraulic fracturing operate in other states, including Pennsylvania may be an option. [8]

(d) How should groundwater and surface water withdrawal for hydraulic fracturing be regulated?

The State of Vermont has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. As such, groundwater and surface water withdrawal for hydraulic fracturing is not allowed.

Groundwater and surface water are valuable resources in Vermont and are protected as a Public Trust Resource. Without proper controls on the rate, timing and location of such water withdrawals, the cumulative impacts of such withdrawals could cause modifications to groundwater levels, surface water levels, and stream flow that could result in significant adverse impacts, including but not limited to impacts to the aquatic ecosystem, downstream river channel and riparian resources, wetlands, and water supplies.[(8) (11)]

If HVHF were to take place in Vermont, the following permits at a minimum, would be required for large groundwater withdrawals and surface water withdrawals.

Permitting – Large Groundwater Withdrawal Permit

In accordance with EPR, Chapter 24, Groundwater Withdrawal Reporting and Permitting Rules, amended June 2011, a Large Groundwater Withdrawal Permit is required for the withdrawal of more than 57,600 gallons per day for non-potable purposes.

Permitting requirements for industrial/commercial withdrawals include the following:

- Develop a water budget for the aquifer(s) the withdrawal is taking place from, considering all inputs and outputs. Identify the source of the data for any assumptions used and the reasoning for their choice in calculating the budget.
- Develop a conceptual hydro-geologic model of the withdrawal, taking into consideration the water budget information, per Chapter 24, Section 24-503.
- Based on the conceptual hydro-geologic model, delineate the potential Area of Influence in plan view, and in profile view show both the preexisting groundwater conditions and the conditions under maximum proposed withdrawal, with both maps at an appropriate scale that can adequately depict the information requested below, per Chapter 24, Section 24-503.
- Describe how the potential Area of Influence was delineated, and when choosing from a range of variables, explain why those values were chosen in developing the potential Area of Influence.
- Inventory of existing groundwater water sources and withdrawals within the potential Area of Influence, with locations identified on the map created above, per Chapter 24, section 24-504.
- Inventory of surface waters and significant wetlands within the proposed Area of Influence, with locations identified on the same map as the inventory of existing groundwater sources, per Chapter 24, Section 24-505.
- Inventory the actual and potential contaminant sources within the potential Area of Influence, with locations identified on the same map as the inventory of groundwater sources, per Chapter 24, Section 24-506.

- Provide a description of the estimated withdrawal effects on each of the contamination sources, surface water resources, groundwater uses, and on the long term response of the aquifer, per Chapter 24, Section 24-507.
- Describe the mitigation measures to be implemented to remedy any expected undue adverse impacts. Include a letter of landowner consent if any activities are to be conducted on their property.
- Provide a description of the Source Testing Program design, prepared in accordance with Chapter 24, Section 24-508.
- Attach a list of all persons that were notified, as required, of this permit application submittal, a copy of the published notification, and verification that each was notified (name and address).

The following findings must be made before issuing a permit:

1. The applicant complied with all public notice requirements; the applicant submitted a complete application;
2. The groundwater is used efficiently;
3. A safe yield for the withdrawal is established;
4. The withdrawal is consistent with town and regional plans and state policy;
5. No undue adverse effect on existing uses, permitted public water systems, significant wetlands or other hydrologically interconnected water resources will occur;
6. Will not violate Vermont water quality standards; and
7. Any other consideration that the Secretary determines necessary for the conservation of water or protection of groundwater quality.

Surface Water Withdrawals

Based on the ANR Procedure for Determining Acceptable Minimum Stream Flows, dated July 14, 1993 and Statute, it is the policy of the State of Vermont to protect and enhance the quality, character and usefulness of surface waters, prevent the degradation of high quality waters, and prevent, abate or control all activities harmful to water quality. It is further the policy to assure the maintenance of water quality necessary to sustain existing aquatic communities and seek over the long term to upgrade the quality of waters and to reduce existing risks to water quality.

At the same time, it is the policy of the State of Vermont to promote a healthy and prosperous agricultural community, to maintain the purity of drinking water and assure the public health, to decrease Vermont's dependence on non-renewable energy sources, and to allow beneficial and environmentally sound development.

Water withdrawals in both streams and lakes usually require one or more permits. Act 250, Stream Alteration (in rivers), or Shoreland Encroachment (in lakes and reservoirs) permits may be needed, as well as a permit from the U.S. Army Corps of Engineers. As with other projects requiring a federal permit, a Section 401 Water Quality Certification from ANR will be required before the permit is issued.

ANR has adopted a standard that defines the standards and process used by the Agency during its review of project proposals. The procedure defines how ANR will determine the minimum streamflow that is necessary to meet Vermont Water Quality Standards.

The foundation of state statutes protecting the natural flow of Vermont's rivers and streams is that the natural flow should be protected and maintained in the public interest. All reasonable alternatives to altering stream flow and water conservation measures should be thoroughly considered before reduction of the natural flow rate is considered.

This procedure may be viewed in three (3) simplified steps. First, ANR will accept the U.S. Fish and Wildlife Service recommended minimum flows of 0.5 csm (cubic feet per second per square mile) (summer), 1.0 csm (fall and winter), and 4.0 csm (spring) as a presumption that stream values and ANR Streamflow Procedure July 14, 1993 uses are protected with little or no further field examination of the water in question or hydrologic computations.

Secondly, applicants may conduct flow gaging of the subject stream to establish a valid statistical relationship with a long- term stream gage station, which relationship would then be used to compute applicable stream flow statistics as used in the U.S. Fish and Wildlife Service policy. (12)

Finally, where an applicant wishes to seek ANR approval for lower conservation flows, applicant may conduct site specific studies such as the U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM) protocols, or other approved habitat assessment methods. Results of valid evaluations, while costly and time consuming, may provide specific habitat information on which to make minimum flow judgments. Where ANR approved evaluations are available, ANR will use this information to make judgments on acceptable low flows, which judgments may be greater or lesser than the U.S. Fish and Wildlife Service presumptive flow recommendation. It should be noted that some streams are not physically conducive to IFIM analysis, other evaluation methods may be necessary, and that IFIM analysis conducted to date tend to support conservation flows at the February median flow value for the fall/winter period. (12)

Decision authority for permits issued under V.S.A. Chapter 43 (Dams); water quality certificates issued pursuant to Section 401 of the Federal Clean Water Act; and stream alteration permits issued under 10 V.S.A. Chapter 41 shall rest with the Commissioner of Environmental Conservation or designee. Decision authority for approvals of fish passage obstructions issued under 10 V.S.A. Section 4607 shall rest with the Commissioner of Fish and Wildlife or designee. Decision authority for positions taken before Act 250 district commissions or subsequent appeals shall rest with the Secretary of ANR or designee. (12)

(e) How land use practices and traffic associated with hydraulic fracturing should be regulated?

The State has enacted laws and rules prohibiting hydraulic fracturing for oil and gas in Vermont. As such, land use practices and traffic associated with HVHF are not regulated.

Generally speaking, if left unchecked, activities associated with HVHF for oil and gas could have significant environmental and socioeconomic impacts on a community. Act 250 is Vermont's land use law and tool for regulating land use practices in Vermont from a State vantage point. Applicants must satisfy 10 relevant "Criteria", prior to receiving a permit or commencing construction, including conformance with local and regional zoning plans. Local and regional planning documents such as zoning, town and regional plans, define and communicate community's immediate and long term goals and provides a foundation for future local laws that may be enacted. (13)

The ability of local governments to use their zoning authority to enact local laws and ordinances addressing hydrofracking has been challenged. Home Rule is the power of a constituent part (administrative division) of a state to exercise such of the state's powers of governance within its own administrative area that have been decentralized to it by the central government. Home rule has been challenged in communities across the U.S. by people and companies with interest in drilling in communities that have chosen to ban high volume hydraulic fracturing.

Notably, a 2007 New York State Court of Appeals decision (Village of Chestnut Ridge vs. Town of Ramapo) observed that "[t]he power to define the community character is a unique prerogative of a municipality acting in its governmental capacity" and, that, generally, through the exercise of their zoning and planning powers, municipalities are given the job of defining their own character. (8) More recently, the New York's Court of Appeals upheld the power of municipalities to prohibit hydraulic fracturing within their boundaries. More than 170 towns and cities have prohibited fracking in New York since 2008. (14)

Additional planning tools may be useful to hydraulic fracturing activities including laws of general applicability, road use regulations and agreements, and host community agreements. Laws of general applicability that may be enacted include those concerning light, noise, dust and odor pollution, stormwater management regulations, wetland provisions, land use provisions concerning industrial uses, erosion control regulations, identification of critical environmental areas, and tree cutting regulations. Local governments should be aware that any local law of general applicability that comes too close to directly regulating hydrofracking, such as noise or light pollution ordinances, may be preempted by State Oil and Gas laws. Therefore, it is important to make ordinances non-discriminatory and generally applicable. (13)

Municipalities must be prepared for pre-drilling, drilling and post-drilling impacts and plan to mitigate and remediate all impacts to its infrastructure including impacts from heavy truck traffic. Traffic impacts result from truck convoys, brine tankers, frac pump trailers, and tractor trailers hauling hundreds of loads of sand. Approximately 5.6 million gallons of water are estimated for each well with potential for multiple wells per site. (13)

Produced water is transported by truck unless a nearby disposal or enhanced recovery project is available to accept the water. As more options for managing produced water become available, other transportation options are being implemented, including transport via pipeline in some areas (either permanently installed or temporary laid on the ground surface). With recycling and reuse of produced water becoming more common, produced water is increasingly transported off-lease to either a storage facility to await further processing (which would entail additional transport) or to a treatment facility. From a treatment facility, the treated produced water would be transported again to a storage facility to await further handling or to a location where the fluid is reused in subsequent well completions. In all these instances, transportation can be accomplished via truck, pipeline (permanent and/or temporary), or even via rail or watercourse. [3]

In New York State and Pennsylvania, Road Use Agreements are used voluntarily between developers and host municipalities. Agreements typically involve a pre- and post-inspection and monitoring throughout activities. The developer pays fees and agrees to remediate damage.

Road Use regulations could specify local haul routes, truck restrictions and weight limits or could exclude certain types of vehicles. Caution should be used not to exclude vehicles desired in a neighborhood such as agricultural vehicles.

Traffic impact studies should be performed once site locations are determined.

(3) Should additional statutory or regulatory authority be enacted or adopted for the regulation of hydraulic fracturing? A summary of the recommended authority.

The State of Vermont has enacted laws (29 V.S.A) and rules (UIC Rules) prohibiting hydraulic fracturing for oil and gas in Vermont. As such, there are no additional statutory or regulatory authority recommendations at this time.

If the State of Vermont were to repeal 29 V.S.A. and allow HVHF or associated activities such as waste disposal, the UIC Rule would require major revisions. Extensive regulations would be promulgated and additional staff resources would be required throughout the Agency of Natural Resources.

Three essential factors in an effective regulatory program include: regulatory coordination, data management, and foundational scientific research. In 2013 the GWPC and the Interstate Oil and Gas Compact Commission (IOGCC) formed the State Oil and Gas Regulatory Exchange (SOGRE), as part of the State's First initiative, that will assist states with reviews and updates of regulations, provide technical training, and facilitate technology transfer. (3) This resource should be used in the event that hydraulic fracturing for oil and gas be considered in the State.

In addition to the extensive rule rewrite and regulations, additional useful tools to supplement regulations pertaining to hydraulic fracturing could include:

- Field Rules (local details may require specific considerations);
- Guidance Manuals, Instructions and Handbooks (Could provide rules combined from multiple agencies, technical guidances, SOPS)
- Policies, Notices and Orders;
- Forms and specific Best Management Practices. (3)

Data management is critical across agency jurisdictions, with regulatory field staff, regulated industries, and the public for the ability to assess trends in energy production, water quality and supply and natural resources.

(4) Summary of consultation with interested parties.

(a) Environmental groups

A common theme among anti-fracking activists can be summed up in Sierra Club's statement: "Increasing reliance on natural gas displaces the market for clean energy and harms human health and the environment in places where production occurs."

Concerns voiced and efforts by the Sierra Club (the "Club") evolve around:

- Air - pollution from truck traffic, diesel generators, gas venting, flaming and leaking air pollutants,
- Water – volume needed, wastewater generated, toxicity, risk to aquifers,
- Climate- Green House Gas
- Public Health – Impose stricter regulations for safer drilling until we can find a cleaner source of energy.

The Club promotes tough federal and state safeguards and repealing the numerous federal exemptions that the natural gas industry enjoys (see Introduction section of this report). They also strive to support local communities that wish to restrict gas development and ensure that gas development is not allowed in areas that are environmentally inappropriate.

The Club's Fracking Policy encourages ongoing improvements in projects and regulations consistent with environmental progress as outlined below.

> "First, the Sierra Club opposes fracking projects if the identity and volume of fracking fluids are not fully disclosed to the public.
>
> Second, the Club opposes any projects using fracking fluids that pose unacceptable toxic risks.
>
> Third, the Club opposes any projects that do not properly treat, manage, and account for fracking fluids, drilling muds, and produced water. All fuels, lubricants, hydraulic fluids and other substances used in drilling, construction and related equipment also must be logged, tracked and managed properly. Fracking should not be permitted unless it can be demonstrated that drinking water aquifers, surface waters, wetlands and any other water bodies are adequately protected from contamination. This provision applies to individual projects and to the cumulative impacts on communities, areas and regions.
>
> Fourth, the Club opposes fracking that would endanger ground or surface water supplies or critical watersheds, seriously damage important wild land resources, significantly increase habitat fragmentation, significantly imperil human health, or otherwise violate the Club's land conservation policies. This provision applies to individual projects and to the cumulative impacts on communities, areas and regions.

Fifth, the Club opposes any fracking projects that would expose workers or others to significant toxic air pollution or cause violations of air quality standards, individually or cumulatively. The club also opposes natural gas projects that do not reduce fugitive methane emissions to acceptable levels.

Sixth, the Club opposes fracking projects in which either venting or flaring of natural gas is practiced without compelling safety or engineering reasons to do so. Where either venting or flaring occur, they must cease as soon as capture equipment can be put in place. Methane is a potent greenhouse gas. Infrastructure must be put in place to capture gases with minimal release into the air.

Seventh, the Club opposes hydraulic fracturing and associated activities which are not preceded by robust, easily accessible public notice and public participation processes at the municipal, state and federal levels, as applicable.

Eighth, the Club opposes any operation where sand extraction and utilization as proppants may cause significant harm to either communities where it is extracted and transported or to workers handling it on site.

Ninth, the Club opposes the transport of water, chemicals, sand, gas or oil by pipeline, truck, or railroad in ways that endanger the health and safety of communities, ecosystems or waterways due to inadequate regulations or infrastructure."

Source:
http://www.sierraclub.org/sites/www.sierraclub.org/files/NaturalGasFracking.pdf

The Clean Water Action and Clean Water Fund (CWA/CWF) recently published two reports [15, 16] that discuss the inadequacies of the Aquifer Exemption Program and the UIC Class II Program to protect drinking water from certain oil and gas and uranium mining activities under the SDWA. These two publications highlight Congressional and regulatory exceptions to these programs:

"Aquifer Exemptions: A First-Ever Look at the Regulatory Program That Writes Off Drinking Water Resources for Oil, Gas and Uranium Profits."

"Regulating Oil & Gas Activities to Protect Drinking Water: The Safe Drinking Water Act's Underground Injection Control Program."

US EPA developed the UIC program in the early days of SDWA implementation. Those with oil and gas interests cited that the SDWA may not prescribe requirements for State UIC programs which interfere with or impede the injection of fluids association with oil and gas production. Extraction proponents argued that certain energy extraction activities would not be able to continue if all underground sources of drinking water everywhere were protected. As a result an aquifer is now eligible for an exemption if it meets certain regulatory criteria. The UIC program allows certain oil and gas and mining activity to occur in groundwater that would otherwise be protected as a drinking water source.

Fundamental concerns with the Aquifer Exemption Program outlined in the report include:

- EPA and at least one state program have admitted to serious documentation problems related to aquifer exemptions. These include the lack of a complete national list of all exempted aquifers, the Statement of Basis for those decisions, and ill-defined boundaries of the exempted aquifers.
- The criteria for granting aquifer exemptions raises concern in light of changes in water supply and demand, new treatment technologies and the impacts of changing climate.
- The criteria is especially ambiguous in determining if water over 3,000 mg/L TDS will not serve as a USDW in the future.
- Industry Influence on development of the UIC program, including Aquifer Exemptions and Section 1425 primacy approval has contributed to a regulatory environment which risks prioritizing energy extraction over protection of USDW.

The report highlights that the depth and quality of an aquifer which could potentially serve as a USDW is far different from when the program was first developed over thirty years ago. EPA officials recognize that advancing technology and climate change have made water sources once deemed inaccessible more likely to be needed, and used, in the future.

(b) The Natural Gas and Oil Resources Board

Vermont's Natural Gas and Oil Resources Board is a five member Board. The Board is currently inactive and does not meet on a regular basis.

The Ground Water Protection Council report referenced throughout this report "State Oil and Gas Regulations Designed to Protect Water Resources" is an update to a 2009 report and includes an overview of 2013 groundwater protection rules in 27 states that account for more than 98 percent of the country's oil and gas production. In addition to the most up-to-date accounting of state regulatory activities, the report includes a series of items states might consider when evaluating and revising their rules and policies regarding hydraulic fracturing, chemical disclosure, and storage and spill prevention. Their report is endorsed by the State Oil and Gas Regulatory Exchange. (3)

(c) The Oil and Gas Industry

In April 2013, the Oil and Gas Industry, particularly the American Petroleum Institute (API) presented "Joint Comments" to the EPA Science Advisory Board (SAB), charged with reviewing the EPA's *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources*, discussed in detail in the next section. A copy of those comments expressing concerns regarding the EPA's study can be found at the following link and are also attached as Appendix C:

http://yosemite.epa.gov/sab/sabproduct.nsf/096328E8F5CBA57B85257B5D007750AC/$File/Public+Comments+submitted+by+Meadows,+Stephanie-Second+Set+of+Comments-4-30-13_Redacted.pdf

The API is a national trade association representing over 500 member companies involved in all aspects of the oil and natural gas industry in the U.S. America's Natural Gas Alliance (ANGA) represents 26 of North America's largest independent natural gas exploration and production companies.

http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/928483abb4f2a13285257b02004ab250!OpenDocument&Date=2013-05-07

(d) U.S. Environmental Protection Agency

EPA Documents are referenced throughout, and provide the regulatory framework for, the report.

The EPA recently published a "Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuel: Underground Injection Control Program Guidance #84 in February 2014. (17) Although the report is based on the use of diesel fuel the EPA recommends it as a general guidance for all unconventional high volume hydraulic fracturing activities for oil and gas.

The questions answered by the guidance are as follows:

- What Information Should Be Submitted with the Permit Application?
- Can Multiple UIC Class II Wells Using Diesel Fuels for HF Be Authorized by One Permit?
- How Should EPA UIC Permit Writers Establish Permit Duration and Apply UIC Class II Requirements After HF at a Well Ceases?
- How Do the Area of Review (AoR) Requirements at 40 CFR 146.6 Apply to Wells Using Diesel Fuels for HF?
- How Do the Class II Well Construction Requirements Apply to HF Wells Using Diesel Fuels?
- How Do the Class II Well Construction Requirements Apply to Already Constructed Wells Using Diesel Fuels for HF?
- How Do the Class II Well Operation, Mechanical Integrity, Monitoring, and Reporting Requirements Apply to HF Wells Using Diesel Fuels?
- How Do the Class II Financial Responsibility Requirements Apply to Wells Using Diesel Fuels for HF?
- What Public Notification Requirements or Special Environmental Justice (EJ) Considerations are Recommended for Authorization of Wells Using Diesel Fuels for HF?

C. Environmental impacts of hydraulic fracturing and the potential impact of the practice on the public health and environment of Vermont.

(1) A summary of the findings of the U.S. Environmental Protection Agency studies of the environmental impacts of hydraulic fracturing, including the effects of hydraulic fracturing on groundwater and air quality.

(a) Effects on Groundwater Quality

Prior to 1997, EPA considered hydraulic fracturing to be a well stimulation technique associated with production and therefore not subject to UIC. The Legal Environmental Assistance Foundation (LEAF) challenged EPA's opinion on hydraulic fracturing regulation in 1994, and the 11th Circuit Court of Appeals ruled that hydraulic fracturing of coalbed methane wells was indeed subject to the SDWA and UIC regulations under Alabama's UIC program in 1997. [18]

In response to the 11th Circuit Court of Appeals decision the State of Alabama supplemented its rules governing the hydraulic fracturing of wells to include additional requirements to protect USDWs during the hydraulic fracturing of coalbeds for methane production. [18]

In the wake of the Court decision, EPA decided to assess the potential for hydraulic fracturing fluid injection into coalbed methane wells to contaminate USDWs. EPA's decision to conduct this study was also based on concerns voiced by individuals who might be affected by coalbed methane development, Congressional interest, and the need for additional information before EPA could make any further regulatory or policy decisions regarding hydraulic fracturing. [18]

EPA began a study on hydraulic fracturing used in coalbed methane reservoirs in 1999. As noted on the EPA website, the study focused on coalbed methane reservoirs because they are typically closer to the surface and in greater proximity to USDWs compared to conventional gas reservoirs. [5]

EPA published the coalbed methane study, *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs* (EPA 816-R-04-003) in 2004. EPA concluded that there was little to no risk of fracturing fluid contaminating underground sources of drinking water during hydraulic fracturing of coalbed methane production wells. A summary of the findings is presented below:

> "EPA, through its UIC Program, conducted a fact-finding effort based primarily on existing literature. The goal of this study was to assess the potential for contamination of USDWs due to the injection of hydraulic fracturing fluids into coalbed methane wells and to determine, based on these findings, whether further study is warranted. For the purposes of this study, EPA assessed USDW impacts by the presence or absence of documented drinking water well contamination cases caused by coalbed methane

hydraulic fracturing, clear and immediate contamination threats to drinking water wells from coalbed methane hydraulic fracturing, and the potential for coalbed methane hydraulic fracturing to result in USDW contamination based on two possible mechanisms as follows:

> Direct injection of fracturing fluids into a USDW in which the coal is located, or injection of fracturing fluids into a coal seam that is already in hydraulic communication with a USDW (e.g., through a natural fracture system).
>
> Creation of a hydraulic connection between the coalbed formation and an adjacent USDW. "

EPA obtained information for this study from literature searches, field visits, a review of reported groundwater contamination incidents in areas where coalbed methane is produced, and solicitation of information from the public on any impacts to groundwater believed to be associated with hydraulic fracturing.

EPA also reviewed 11 major coal basins throughout the United States to determine if coalbeds are co-located with USDWs and to understand the coalbed methane activity in the area. In its final study design, EPA indicated that the Agency would make a determination regarding whether further investigation was needed after analyzing the Phase I information. Specifically, EPA determined that it would not continue into Phase II of the study if the investigation found that no hazardous constituents were used in fracturing fluids, hydraulic fracturing did not increase the hydraulic connection between previously isolated formations, and reported incidents of water quality degradation could be attributed to other, more plausible causes. (18)

EPA concluded,

"Based on the information collected and reviewed, EPA has concluded that the injection of hydraulic fracturing fluids into coalbed methane wells poses little or no threat to USDWs and does not justify additional study at this time. This decision is consistent with the process outlined in the April, 2001 Final Study Design, in which EPA indicated that it would determine whether further investigation was needed after analyzing the Phase I information. Specifically, EPA determined that it would not continue into Phase II of the study if the investigation found that no hazardous constituents were used in fracturing fluids, hydraulic fracturing did not increase the hydraulic connection between previously isolated formations, *and* reported incidents of water quality degradation were attributed to other, more plausible causes.

Although potentially hazardous chemicals may be introduced into USDWs when fracturing fluids are injected into coal seams that lie within USDWs, the risk posed to USDWs by introduction of these chemicals is reduced significantly by groundwater production and injected fluid recovery, combined with the mitigating effects of dilution and dispersion, adsorption, and potentially biodegradation. Additionally, EPA has reached an agreement with the major service companies to voluntarily eliminate diesel

> fuel from hydraulic fracturing fluids that are injected directly into USDWs for coalbed methane production.
>
> Often, a high stress contrast between adjacent geologic strata results in a barrier to fracture propagation. This may occur in those coal zones where there is a geologic contact between a coalbed and a thick, higher-stress shale that is not highly fractured. Some studies that allow direct observation of fractures (i.e., mined-through studies) indicate many fractures that penetrate into, or sometimes through, formations overlying coalbeds can be attributed to the existence of pre-existing natural fractures. However, and as noted above, given the concentrations and flowback of injected fluids, and the mitigating effects of dilution and dispersion, fluid entrapment, and potentially biodegradation, EPA does not believe that possible hydraulic connections under these circumstances represent a significant potential threat to USDWs." (18)

The report was criticized by longtime EPA scientist Weston Wilson who wrote to Colorado representatives stating that the report is "unsound", invoking protections under the First Amendment of the Constitution and the Whistleblowers Protection Act should EPA retaliate against him. (19) A copy of his letter and technical analysis is included as Appendix D.

Wilson provided a technical analysis of the EPA Report which makes, in part, the following points:

- EPA should have conducted further investigation based on its findings.
- EPA did not investigate pathways for unwanted methane migration
- Five members of the EPA's Peer Review Team appear to have conflicts-of-interest
- EPA did not include in its Peer Review any EPA expert nor did EPA include its most experienced professional staff to participate in its study of hydraulic fracturing of coal bed methane reservoirs
- Three service companies have agreed not to inject diesel fuel in hydraulic fluids used for hydraulic of coal bed methane reservoirs.
- The oil and gas industry is now seeking to exempt the practice of hydraulic fracturing from the requirements of the SWDA
- The public should be wary of exempting this practice from compliance with the Safe Drinking Water Act.

The 2004 EPA study is often referred to as the scientific basis for exempting fracking from the Underground Injection Control provisions of the Safe Water Drinking Act, included in the 2005 Energy Policy Act (a.k.a the "Halliburton Loop Hole"). (19)

"In response to escalating public concerns and the anticipated growth in oil and natural gas exploration and production, the US Congress directed EPA in fiscal year 2010 to conduct research to examine the relationship between hydraulic fracturing and drinking water resources." (10)

The EPA published a *Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* in consultation with stakeholders and the EPA's Science Advisory Board (SAB) on February 7, 2011. (21)

The SAB presented detailed comments of the Study to the EPA in their letter dated August 4, 2011. (22)

The final "*Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources"* was published by the EPA in November, 2011. (10) The following is a summary, based on the EPA Plan, of the awaited study's objectives and scope.

> "The overall purpose of this study is to elucidate the relationship, if any, between hydraulic fracturing and drinking water resources. More specifically, the study has been designed to assess the potential impacts of hydraulic fracturing on drinking water resources and to identify the driving factors that affect the severity and frequency of any impacts.
>
> The scope of the research includes the hydraulic fracturing water use lifecycle, which is a subset of the greater hydrologic cycle. For the purposes of this study, the hydraulic fracturing water lifecycle begins with water acquisition from surface or ground water and ends with discharge into surface waters or injection into deep wells. Specifically, the water lifecycle for hydraulic fracturing consists of water acquisition, chemical mixing, well injection, flowback and produced water (collectively referred to as "hydraulic fracturing wastewater"), and wastewater treatment and waste disposal.
>
> The EPA study is designed to provide decision-makers and the public with answers to the five fundamental questions associated with the hydraulic fracturing water lifecycle:
>
> • Water Acquisition: What are the potential impacts of large volume water withdrawals from ground and surface waters on drinking water resources?
>
> • Chemical Mixing: What are the possible impacts of surface spills on or near well pads of hydraulic fracturing fluids on drinking water resources?
>
> • Well Injection: What are the possible impacts of the injection and fracturing process on drinking water resources?
>
> • Flowback and Produced Water: What are the possible impacts of surface spills on or near well pads of flowback and produced water on drinking water resources?
>
> • Wastewater Treatment and Waste Disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?
>
> The Agency will use existing data from hydraulic fracturing service companies and oil and gas operators, federal and state agencies, and other sources. To supplement this information, EPA will conduct case studies in the field and generalized scenario evaluations using computer modeling. Where applicable, laboratory studies will be conducted to provide a better understanding of hydraulic fracturing fluid and shale rock interactions, the treatability of hydraulic fracturing wastewaters, and the toxicological characteristics of high-priority constituents of concern in hydraulic fracturing fluids and wastewater. EPA has also included a screening analysis of whether hydraulic fracturing activities may be disproportionately occurring in communities with environmental justice concerns.

Existing data will be used answer research questions associated with all stages of the water lifecycle, from water acquisition to wastewater treatment and waste disposal. EPA has requested information from hydraulic fracturing service companies and oil and gas well operators on the sources of water used in hydraulic fracturing fluids, the composition of these fluids, well construction practices, and wastewater treatment practices. EPA will use these data, as well as other publically available data, to help assess the potential impacts of hydraulic fracturing on drinking water resources.

Retrospective case studies will focus on investigating reported instances of drinking water resource contamination in areas where hydraulic fracturing has already occurred. EPA will conduct retrospective case studies at five sites across the US. The sites will be illustrative of the types of problems that have been reported to EPA during stakeholder meetings held in 2010 and 2011. A determination will be made on the presence and extent of drinking water resource contamination as well as whether hydraulic fracturing contributed to the contamination. The retrospective sites will provide EPA with information regarding key factors that may be associated with drinking water contamination.

Prospective case studies will involve sites where hydraulic fracturing will occur after the research is initiated. These case studies allow sampling and characterization of the site before, during, and after water acquisition, drilling, hydraulic fracturing fluid injection, flowback, and gas production. EPA will work with industry and other stakeholders to conduct two prospective case studies in different regions of the US. The data collected during prospective case studies will allow EPA to gain an understanding of hydraulic fracturing practices, evaluate changes in water quality over time, and assess the fate and transport of potential chemical contaminants.

Generalized scenario evaluations will use computer modeling to allow EPA to explore realistic hypothetical scenarios related to hydraulic fracturing activities and to identify scenarios under which hydraulic fracturing activities may adversely impact drinking water resources.

Laboratory studies will be conducted on a limited, opportunistic basis. These studies will often parallel case study investigations. The laboratory work will involve characterization of the chemical and mineralogical properties of shale rock and potentially other media as well as the products that may form after interaction with hydraulic fracturing fluids. Additionally, laboratory studies will be conducted to better understand the treatment of hydraulic fracturing wastewater with respect to fate and transport of flowback or produced water constituents.

Toxicological assessments of chemicals of potential concern will be based primarily on a review of available health effects data. The substances to be investigated include chemicals used in hydraulic fracturing fluids, their degradates and/or reaction products, and naturally occurring substances that may be released or mobilized as a result of hydraulic fracturing. It is not the intent of this study to conduct a complete health assessment of these substances. Where data on chemicals of potential concern are limited, however, quantitative structure-activity relationships—and other approaches—may be used to assess toxicity. (10)

A Progress Report was published in 2012. (5) This report primarily provides an update of the methods used for the investigation and progress to date, but provides limited actual data or results. For example it indicates how when and where groundwater samples were collected but no or limited data.

Median concentrations of selected chemicals and conductivity of effluent treated and discharged from two wastewater treatment facilities that accept oil and gas wastewater were presented. Discharge A is located on the Allegheny River and Discharge B is located on Blacklick Creek, both in Pennsylvania. The EPA collected samples beginning on May 16, 2012. (5) The following data was included.

Measurement (milligrams per liter)	Discharge A	Discharge B
Chloride	49,875	97,963
Bromide	506	779
Sulfate	679	976
Sodium	20,756	38,394

The EPA is assessing the ability of hydraulic fracturing wastewater to contribute to disinfection byproduct (DBP) formation in drinking water treatment facilities, with a particular focus on the formation of brominated DBPs. (5)

Wastewaters from hydraulic fracturing processes typically contain high concentrations of TDS including significant concentrations of chloride and bromide. These halogens are difficult to remove from wastewater; if discharged from treatment works, they can elevate chloride and bromide concentrations in drinking water sources. Upon chlorination at a drinking water treatment facility, chloride and bromide can react with naturally occurring organic matter (NOM) in the water and lead to the formation of DBPs. Because of their carcinogenicity and reproductive and developmental affects, the maximum contaminant levels (MCLs) of the DBPs bromate, chlorite, haloacetic acids, and total Trihalomethanes (THMs) in finished drinking water are regulated by the National Primary Drinking Water Regulations. (5)

Increased bromide concentrations in drinking water resources can lead to greater total THM concentrations on a mass basis and may make it difficult for some public water supplies (PWSs) to meet the regulatory limits of total THM. It is important to note that hydraulic fracturing wastewater can potentially contain other contaminants in significant concentrations that could affect human health. The EPA identified the impacts of elevated bromide and chloride levels in surface water from hydraulic fracturing wastewater discharge as a priority for protection of public water supplies. (5)

Hydraulic fracturing-related chemicals include chemicals used in the injected fracturing fluid, chemicals found in flowback and produced water, and chemicals resulting from the treatment of hydraulic fracturing wastewater (e.g., chlorination or bromination at wastewater treatment facilities). Some of these chemicals are present due to the mobilization of naturally occurring chemicals within the geologic formations or through the degradation or reaction of the injected chemicals in the different environments (i.e., subsurface, surface and wastewater). The EPA has identified over 1,000 chemicals that are reported to be used in fracturing fluids or found in hydraulic fracturing wastewaters; these range from the inert and innocuous, such as sand and water, to reactive and toxic chemicals, like alkylphenols and radionuclides. (5)

The following table is a list of chemicals identified for analytical method testing activities in the EPA Progress Report. (5)

Chemical Class	Chemical Name(s)	CASRN	Purpose in Hydraulic Fracturing	Reason Selected
Alcohols	Propargyl alcohol	107-19-7	Corrosion inhibitor	Toxicity, frequency of use
	Methanol	67-56-1		
	Isopropanol	67-63-0		
	t-Butyl alcohol	75-65-0	Byproduct of t-butyl hydroperoxide	
Aldehydes	Glutaraldehyde	111-30-8	Biocide	Toxicity, frequency of use
	Formaldehyde	50-00-0	Biocide	
Alkylphenols	Octylphenol	27193-28-8	Surfactant	Toxicity, frequency of use
	Nonylphenol	84852-15-3		
Alkylphenol ethoxylates	Octylphenol ethoxylate	9036-19-5	Surfactant	Frequency of use
	Nonylphenol ethoxylate	26027-38-3		
Amides	Thiourea	62-56-6	Corrosion inhibitor	Toxicity
	Acrylamide	79-06-1	Friction reducer	Toxicity, frequency of use, requested by EPA researchers
	2,2-Dibromo-3-nitrilopropionamide	10222-01-2	Biocide	
Amines (alcohol)	Diethanolamine	111-42-2	Foaming agent	Frequency of use
Aromatic hydrocarbons	BTEX, naphthalene, benzyl chloride, light petroleum hydrocarbons		Gelling agents, solvents	Toxicity, frequency of use, requested by EPA researchers
Carbohydrates	Polysaccharides		Byproduct	Requested by EPA researchers
Disinfection byproducts	Trihalomethanes, haloacetic acids, N-nitrosamines*		Byproduct	Toxicity
Ethoxylated alcohols	Ethoxylated alcohols, C8–10 and C12–18	68954-94-9	Surfactant	Frequency of use

Chemical Class	Chemical Name(s)	CASRN	Purpose in Hydraulic Fracturing	Reason Selected
Glycols	Ethylene glycol	107-21-1	Crosslinker, breaker, scale inhibitor	Frequency of use
	Diethylene glycol	111-46-6		
	Triethylene glycol	112-27-6		
	Tetraethylene glycol	112-60-7		
	2-Methoxyethanol†	109-86-4	Foaming agent	
	2-Butoxyethanol†	111-76-2		
Halogens	Chloride	16887-00-6	Brine carrier fluid, breaker	Frequency of use
Inorganics	Barium	7440-39-3	Mobilized during hydraulic fracturing	Toxicity, frequency of use of potassium and sodium salts, mobilization of naturally occurring ions
	Strontium	7440-24-6	Mobilized during hydraulic fracturing	
	Boron	7440-42-8	Crosslinker	
	Sodium	7440-23-5	Brine carrier fluid, breaker	
	Potassium	7440-09-7	Brine carrier fluid	
Radionuclides	Gross α		Mobilized during hydraulic fracturing	Toxicity, mobilization of naturally occurring ions
	Gross β			
	Radium	13982-63-3		
	Uranium	7440-61-1		
	Thorium	7440-29-1		

The following chemicals were identified as being associated with hydraulic fracking as listed in the EPA Progress Report. (5)

Glycols and Related Compounds Glycols (diethylene glycol, triethylene glycol, and tetraethylene glycol) and the chemically related compounds 2-butoxyethanol and 2-methoxyethanol are frequently used in hydraulic fracturing fluids and not naturally found in ground water. Thus, they may serve as reliable indicators of contamination of ground water from hydraulic fracturing activities.

Acrylamide is often used as a friction reducer in injected hydraulic fracturing fluids.

Ethoxylated Alcohols Surfactants are often added to hydraulic fracturing fluids to decrease liquid surface tension and improve fluid passage through pipes. Most of the surfactants used are alcohols or some derivative of an ethoxylated compound, typically ethoxylated alcohols. Many ethoxylated alcohols and ethoxylated alkylphenols biodegrade in the environment, but often the degradation byproducts are toxic (e.g., nonylphenol, a degradation product of nonylphenol ethoxylate, is an endocrine disrupting compound).

Disinfection Byproducts Flowback and produced water can contain high levels of TDS, which may include bromide and chloride (as discussed above). In some cases, treatment of flowback and produced water occurs at WWTFs, which may be unable to effectively remove bromide and chloride from hydraulic fracturing wastewater before discharge. The presence of bromide ions in drinking source waters undergoing chlorination disinfection may lead to the formation of brominated DBPs—including bromate, THMs, and HAAs—upon reaction with natural organic material. Brominated DBPs are considerably more toxic than corresponding chlorinated DBPs and have higher molecular weight. Therefore, on an equal molar basis, brominated DBPs will have a greater concentration by weight than chlorinated DBPs, hence leading to a greater likelihood of exceeding the total THM and HAA MCLs that are stipulated in weight concentrations (0.080 and 0.060 milligrams per liter, respectively). Accordingly, it is important to assess and quantify the effects of flowback and produced water on DBP generation.

Radionuclides Gross α and β analyses measure the radioactivity associated with gross α and gross β particles that are released during the natural decay of radioactive elements, such as uranium, thorium, and radium. Gross α and β analyses are typically used to screen hydraulic fracturing wastewater in order to assess gross levels of radioactivity. This information can be used to identify waters needing radionuclide-specific characterization.

Inorganic Chemicals In addition to the potential mobilization of naturally occurring radioactive elements, hydraulic fracturing may also release other elements from the fractured shales, tight sands, and coalbeds, notably heavy metals such as barium and strontium. Inorganic compounds may also be added to hydraulic fracturing fluids to perform various functions (e.g., cross-linkers using borate salts, brine carrier fluids using potassium chloride, and pH-adjusting agents using sodium carbonates).

Toxicity Assessment

The US House of Representatives' Committee on Energy and Commerce Minority Staff released a report (2011) noting that more than 650 products (i.e., chemical mixtures) used in hydraulic fracturing contain 29 chemicals that are either known or possible human carcinogens or are currently regulated under the SDWA. However, the report did not characterize the inherent chemical properties and potential toxicity of many of the reported compounds. The identification of inherent chemical properties will facilitate the development of models to predict environmental fate, transport, and the toxicological properties of chemicals. Through this level of understanding, scientists can design or identify more sustainable alternative chemicals that minimize or even avoid many fate, transport, and toxicity issues, while maintaining or improving commercial use. (5)

The EPA is including 5 retrospective Case Studies in the Study.

Las Animas and Huerfano Counties, Colorado

Investigation of potential drinking water impacts from coalbed methane extraction in the Raton Basin

Dunn County, North Dakota

Investigation of potential drinking water impacts from a well blowout during hydraulic fracturing for oil in the Bakken Shale

Bradford County, Pennsylvania

Investigation of potential drinking water impacts from shale gas development in the Marcellus Shale

Washington County, Pennsylvania

Investigation of potential drinking water impacts from shale gas development in the Marcellus Shale

Wise County, Texas

Investigation of potential drinking water impacts from shale gas development in the Barnett Shale

The EPA report completion target date was 2014 but has not been published as of this writing. The current schedule for release of the draft Report of Results to the public is early next year, in 2015, as noted by EPA Administrator Gina McCarthy in a September 16, 2014 Inside EPA daily journal article. (Ed Hanlon, pers. comm. 2014)

A repository for peer reviewed research papers associated with the EPA Study is available at the following link, http://www2.epa.gov/hfstudy/published-scientific-papers. To date, research papers are only submitted under the categories of "Laboratory" and "Subsurface Modeling". The development of specific laboratory methods and subsurface modeling tools were necessary for use in the comprehensive study.

The EPA's SAB and SAB's Hydraulic Fracturing Research Advisory Panel has conducted and will conduct activities associated with the review of EPA's research activities regarding its Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. When this SAB Panel meets or holds a teleconference, the SAB Staff Office provides opportunity for the public to provide oral and written comments for the Panel member's consideration associated with the activity that is being conducted. (Ed Hanlon, pers. comm. 2014)

http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/928483abb4f2a13285257b02004ab250!OpenDocument&Date=2013-05-07

In November 2013, the Panel held a teleconference briefing for the purpose of providing the public with opportunity to provide new and emerging information related to hydraulic fracturing for consideration by the SAB Hydraulic Fracturing Research Advisory Panel. Written public comments were received and posted on the website for this teleconference, and oral public comments were provided and summarized in the teleconference minutes that are also posted on this website at

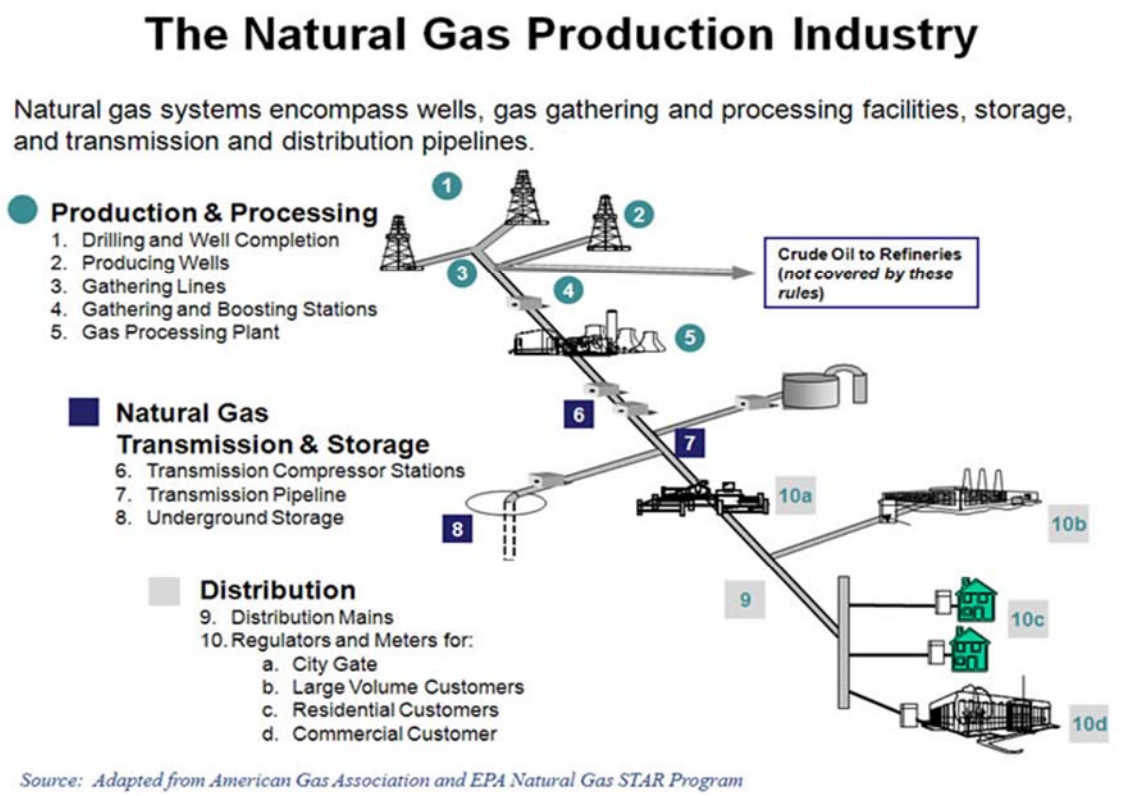
http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/bcdc0be7c8d18b1685257ba30071a755!OpenDocument&Date=2013-11-20 (Ed Hanlon, pers. comm. 2014)

(b) Effects on Air Quality

This basic information was obtained from the US EPA website:

> The oil and natural gas industry includes a wide range of operations and equipment, from wells to natural gas gathering lines and processing facilities, to storage tanks, and transmission and distribution pipelines.
>
> The industry is the largest industrial source of emissions of volatile organic compounds (VOCs), a group of chemicals that contribute to the formation of ground-level ozone (smog). Exposure to ozone is linked to a wide range of health effects, including aggravated asthma, increased emergency room visits and hospital admissions, and premature death. EPA estimates VOC emission from the oil & natural gas industry at 2.2 million tons a year in 2008.
>
> The oil and natural gas industry also is a significant source of emissions of methane, a greenhouse gas that is more than 20 times as potent as carbon dioxide. Emissions of air toxics such as benzene, ethylbenzene, and n-hexane, also come from this industry. Air toxics are pollutants known, or suspected of causing cancer and other serious health effects.
>
> Data provided to EPA's Natural Gas Star Program show that some of the largest air emissions in the natural gas industry occurs as natural gas wells that have been fractured are being prepared for production. During a state of well completion known as "flowback" fracturing fluids, water and reservoir gas come to the surface at a high velocity and volume. This mixture includes a high volume of VOCs and methane, along with air toxics such as benzene, ethylbenzene and n-hexane. The typical flow back process lasts from three to 10 days. Pollution also is emitted from other processes and equipment in the industry that prepare gas for sale and that assist in moving it through pipelines.
>
> The gas the wells produce goes to gathering and boosting stations that take it to processing plants. These plants remove contaminant to make the gas ready for the pipelines to deliver it to commercial, industrial and residential customers. Transmission compression stations help move the gas through 1.5 million miles of natural gas pipelines across the U.S.

Source: Overview of Final Amendments to Air Regulations for the Oil and Natural Gas industry. EPA Factsheet.



The following excerpts are extracted from the EPA Oil and Natural Gas Air Pollution Standards webpage:

"On April 17, 2012, the U.S. Environmental Protection Agency (EPA) issued cost-effective regulations, required by the Clean Air Act, to reduce harmful air pollution from the oil and natural gas industry while allowing continued, responsible growth in U.S. oil and natural gas production. The final rules were based on proven technologies and best practices that were already in use to reduce emissions of smog-forming VOCs. The final rules include the first federal air standards for natural gas wells that are hydraulically fractured, along with requirements for several other sources of pollution in the oil and gas industry that currently are not regulated at the federal level.

The final rules are expected to yield a nearly 95 percent reduction in VOC emissions from more than 11,000 new hydraulically fractured gas wells each year. This significant reduction would be accomplished primarily through capturing natural gas that currently escapes into the air, and making that gas available for sale. The rules also will reduce air toxics, which are known or suspected of causing cancer and other serious health effects, and emissions of methane, a potent greenhouse gas.

The final action includes the review of four rules for the oil and natural gas industry: a new source performance standard for VOCs; a new source performance standard for sulfur dioxide; an air toxics standard for oil and natural gas production; and an air toxics standard for natural gas transmission and storage."

In March, 2014, the White House issued a Climate Action Plan Strategy to Reduce Methane Emissions.

"On April 15, 2014, EPA released for external peer review five technical white papers on potentially significant sources of emissions in the oil and gas sector. The white papers focus on technical issues covering emissions and mitigation techniques that target methane and VOCs. As noted in the Obama Administration's Strategy to Reduce Methane Emissions EPA will use the papers, along with the input we receive from the peer reviewers and the public, to determine how to best pursue additional reductions from these sources."

The five white papers cover (Excerpt from the EPA website):
Compressors: Compressors are mechanical devices that increase the pressure of natural gas and allow the natural gas to be transported along a pipeline. Vented emissions of methane and VOCs from compressors occur from seal degassing for wet seal centrifugal compressors or packing surrounding the mechanical compression components of reciprocating compressors. These emissions typically increase over time as the compressor components begin to degrade. This paper presents data and mitigation techniques for emissions from these compressors, some of which are not covered under EPA's 2012 New Source Performance Standards (NSPS) for VOCs.

Emissions from completions and ongoing production of hydraulically fractured oil wells: Completion is the process of preparing a well for production. Completions of hydraulically fractured or refractured oil wells can be a source of methane and VOC emissions. Hydraulically fractured oil wells also may produce natural gas along with the oil; this gas is often vented during production. This paper presents data and mitigation techniques for emissions from completions and associated gas from ongoing production at hydraulically fractured oil wells, which are not covered under the 2012 NSPS.

Leaks: As oil and gas production from unconventional formations such as shale deposits continues to grow, so does the amount of related equipment that has the potential to leak. This paper presents data and mitigation techniques for onshore natural gas leak emissions that occur from natural gas production, processing, transmission and storage.

Liquids unloading: Liquids unloading refers to a number of processes used to remove accumulated liquids that can impede the flow of gas from a well to the surface. This paper presents data and mitigation techniques for the methane and VOC emissions that can occur during these processes. Liquids unloading is not covered under EPA's 2012 NSPS for VOCs.

Pneumatic devices**:** Controllers and pumps powered by high-pressure natural gas are widespread in the oil and natural gas industry. These pneumatic devices may release gas – including methane and VOCs – with every valve movement, or continuously in many cases. This paper presents data and mitigation techniques for emissions from pneumatic controllers and pumps, some of which are not covered under EPA's 2012 NSPS for VOCs.

(2) A summary of additional relevant peer review studies related to the environmental impacts of hydraulic fracturing.

The following section outlines environmental impacts of hydraulic fracturing using the Revised Draft Supplemental Generic Environmental Impact Statement (dSGEIS) from New York State as a backdrop for additional relevant peer reviews where available and as time allowed. New York is relevant to Vermont geographically, topographically, climatically and to some extent geologically. New York currently has a moratorium on fracking pending review of the dSGEIS by the New York Public Health Department.

The study has been vetted by various divisions within the New York Department of Environmental Conservation including the divisions of Water, Air Resources, Lands and Forests, Fish, Wildlife and Marine Resources and assisted by the New York State Energy and Research & Development Authority, Department of Health, Bureaus of Water Supply Protection, Toxic Substance Assessment, Environmental Radiation Protection, Office of Climate Change, Divisions of Materials Management, Environmental Permits, Environmental Remediation, with research assistance from Alpha Environmental, Inc. ICF International, URS Corporation and NTC Consultants and Sammons/Dutton LLC.

The Generic Environmental Impact Statement (GEIS) was developed in 1992 and has evolved to address high volume hydraulic fracturing into a Draft Supplemental Generic Environmental Impact Statement (SGEIS). Written and verbal comments from all interested parties were considered in the preparation of the Final Scope. The Draft SGEIS was released for additional public review and comment. More than 13,000 comments were received. In December 13, 2010 Governor Paterson ordered DEC to conduct further environmental review to ensure that all environmental and public health impacts are mitigated or avoided and to present this information to the public for further review. DEC released the Revised Draft SGEIS and supporting socioeconomic study and more than 60,000 comments were received until the close of the comment period on January 11, 2012. A Final SGEIS was not available at the time of this writing.

Environmental Impacts associated with unconventional high volume hydraulic fracturing on various media as presented in Chapter 6 of the SGEIS is presented below. [8] A summary of the table of contents pertaining to environmental issues associated with oil and gas development is a testament in itself to the far reaching potential impacts and is modified and included below.

WATER RESOURCES

Water Withdrawals

- Reduced Stream Flow Degradation of a Stream's Best Use
- Impacts to Aquatic Habitat
- Impacts to Aquatic Ecosystems
- Impacts to Wetlands
- Aquifer Depletion
- Cumulative Water Withdrawal Impacts
- Stormwater Runoff
- Surface Spills and Releases at the Well Pad
- Drilling
- Hydraulic Fracturing Additives

- Flowback Water and Production Brine
- Potential Impacts to Primary and Principal Aquifers
- Groundwater Impacts Associated With Well Drilling and Construction
- Turbidity
- Fluids Pumped Into the Well
- Natural Gas Migration
- Unfiltered Surface Drinking Water Supplies: NYC and Syracuse
- Pollutants of Critical Concern in Unfiltered Drinking Water Supplies
- Regulatory and Programmatic Framework for Filtration Avoidance
- Adverse Impacts to Unfiltered Drinking Waters from High-Volume Hydraulic Fracturing
- Hydraulic Fracturing Procedure
- Wellbore Failure
- Subsurface Pathways
- Waste Transport
- Fluid Discharges
- POTWs
- Private Off-site Wastewater Treatment and/or Reuse Facilities
- Private On-site Wastewater Treatment and/or Reuse Facilities
- Disposal Wells
- Other Means of Wastewater Disposal
- Solids Disposal
- NORM Considerations - Cuttings
- Cuttings Volume
- Cuttings and Liner Associated With Mud-Drilling

FLOODPLAINS

FRESHWATER WETLANDS

ECOSYSTEMS AND WILDLIFE

- Impacts of Fragmentation to Terrestrial Habitats and Wildlife
- Impacts of Grassland Fragmentation
- Impacts of Forest Fragmentation
- Invasive Species
- Terrestrial
- Aquatic
- Impacts to Endangered and Threatened Species
- Impacts to State-Owned Lands

AIR QUALITY

- Regulatory Overview
- Emission Analysis NOx
    - Internal Combustion Engine Emissions
- Natural Gas Production Facilities NESHAP 40 CFR Part 63, Subpart HH (Glycol Dehydrators)
- Flaring Versus Venting of Well site Air Emissions
- Number of Wells Per Pad Site

- Natural Gas Condensate Tanks
- Emissions Tables
- Offsite Gas Gathering Station Engine
- Department Determinations on the Air Permitting Process Relative to Marcellus Shale High Volume Hydraulic Fracturing Development Activities
- Air Quality Impact Assessment
- Introduction
- Sources of Air Emissions and Operational Scenarios
- Modeling Procedures
- Results of the Modeling Analysis
- Supplemental Modeling Assessment for Short Term PM2.5, SO2 and NO2 Impacts and Mitigation
- Measures Necessary to Meet NAAQS.
- The Practicality of Mitigation Measures on the Completion Equipment and Drilling Engines
- Regional Emissions of O3 Precursors and Their Effects on Attainment Status in the SIP
- Air Quality Monitoring Requirements for Marcellus Shale Activities
- Permitting Approach to the Well Pad and Compressor Station Operations

GREENHOUSE GAS EMISSIONS

- Greenhouse Gases
- Emissions from Oil and Gas Operations
- Vented Emissions
- Combustion Emissions
- Fugitive Emissions
- Emissions Source Characterization
- Emission Rates
- Drilling Rig Mobilization, Site Preparation and Demobilization
- Completion Rig Mobilization and Demobilization
- Well Drilling
- Well Completion
- Well Production

NATURALLY OCCURRING RADIOACTIVE MATERIALS IN THE MARCELLUS SHALE

SOCIOECONOMIC IMPACTS

- Economy, Employment, and Income
- Cyclical Nature of the Natural Gas Industry
- Property Values
- Government Revenue and Expenditures
- Environmental Justice

VISUAL IMPACTS

- Changes since Publication of the 1992 GEIS that Affect the Assessment of Visual Impacts
- Equipment and Drilling Techniques
- Changes in Well Pad Size and the Number of Water Storage Sites
- Duration and Nature of Drilling and Hydraulic-Fracturing Activities

- New Landscape Features Associated with the Different Phases of Horizontal Drilling and Hydraulic
- Fracturing
- New Landscape Features Associated with the Construction of Well Pads
- New Landscape Features Associated with Drilling Activities at Well Pads
- New Landscape Features Associated with Hydraulic Fracturing Activities at Well Pads
- New Landscape Features Associated with Production at Viable Well Sites
- New Landscape Features Associated with the Reclamation of Well Sites
- Visual Impacts Associated with the Different Phases of Horizontal Drilling and Hydraulic Fracturing
- Visual Impacts Associated with Construction of Well Pads
- Visual Impacts Associated with Drilling Activities on Well Pads
- Visual Impacts Associated with Hydraulic Fracturing Activities at Well Sites
- Visual Impacts Associated with Production at Well Sites
- Visual Impacts Associated with the Reclamation of Well Sites
- Visual Impacts of Off-site Activities Associated with Horizontal Drilling and Hydraulic Fracturing
- Previous Evaluations of Visual Impacts from Horizontal Drilling and Hydraulic Fracturing
- Assessment of Visual Impacts using NYSDEC Policy and Guidance

NOISE

- Access Road Construction
- Well Site Preparation
- High-Volume Hydraulic Fracturing – Drilling
- High-Volume Hydraulic Fracturing – Fracturing
- Transportation
- Gas Well Production

TRANSPORTATION IMPACTS

- Estimated Truck Traffic
- Total Number of Trucks per Well
- Temporal Distribution of Truck Traffic per Well
- Temporal Distribution of Truck Traffic for Multi-Well Pads
- Increased Traffic on Roadways
- Damage to Local Roads, Bridges, and other Infrastructure
- Damage to State Roads, Bridges, and other Infrastructure
- Operational and Safety Impacts on Road Systems
- Transportation of Hazardous Materials
- Impacts on Rail and Air Travel

COMMUNITY CHARACTER IMPACTS

SEISMICITY

- Hydraulic Fracturing-Induced Seismicity
- Recent Investigations and Studies
- Correlations between New York and Texas
- Effects of Seismicity on Wellbore Integrity

(a) *Water Resources Impacts (Source NYSDEC, 2011 (8)*

Surface Water Impacts

"Water for hydraulic fracturing may be obtained by withdrawing it from surface water bodies away from the well site or through new or existing water-supply wells drilled into aquifers. … without proper controls on the rate, timing and location of such water withdrawals, the cumulative impacts of such withdrawals could cause modifications to groundwater levels, surface water levels, and stream flow that could result in significant adverse impacts, including but not limited to impacts to the aquatic ecosystem, downstream river channel and riparian resources, wetlands, and aquifer supplies."

Volumes

"Using an industry estimate of a yearly peak activity in New York of 2,462 wells, the dSGEIS estimates that high-volume hydraulic fracturing would result in a calculated peak annual fresh water usage of 9 billion gallons. Total daily fresh water withdrawal in New York has been estimated at about 10.3 billion gallons. This equates to an annual total of about 3.8 trillion gallons. Based on this calculation, at peak activity high-volume hydraulic fracturing would result in increased demand for fresh water in New York of 0.24%. Thus, water usage for high volume hydraulic fracturing represents a very small percentage of water usage throughout the state. Nevertheless, as noted, the cumulative impact of water withdrawals, if such withdrawals were temporally proximate and from the same water resource, could potentially be significant."

Stormwater Runoff

.."the potential impacts on water resources from stormwater flow associated with the construction and operation of high-volume hydraulic fracturing well pads. 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."

Spills

"The dSGEIS concludes that spills or releases in connection with high-volume hydraulic fracturing could have significant adverse impacts on water resources. The dSGEIS identifies a significant number of contaminants contained in fracturing additives, or otherwise associated with high-volume hydraulic fracturing operations. Spills or releases can occur as a result of tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or improper operations. Spilled, leaked or released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers."

Drilling Activities

"….potential significant adverse impacts on groundwater resources from well drilling and construction associated with high-volume hydraulic fracturing. Those potential impacts include impacts from turbidity, fluids pumped into or flowing from rock formations penetrated by the well, and contamination from natural gas present in the rock formations penetrated by the well. ..because of the concentrated nature of the activity on multi-well pads and the larger fluid volumes and pressures associated with high-volume hydraulic fracturing, enhanced procedures and mitigation measures are proposed and described in a supporting study for this dSGEIS concludes that it is highly unlikely that groundwater contamination would occur by fluids escaping from the wellbore for hydraulic fracturing. The 2009 dSGEIS further observes that regulatory officials from 15 states recently testified that groundwater contamination as a result of the hydraulic fracturing process in the tight formation itself has not occurred."

"Gelling agents, surfactants and chlorides are identified in the 1992 GEIS as the flowback water components of greatest environmental concern. Other flowback components can include other dissolved solids, metals, biocides, lubricants, organics and radionuclides. Opportunities for spills, leaks, and operational errors during the flowback water recovery stage are the same as they are during the prior stages with additional potential releases from:

- hoses or pipes used to convey flowback water to tanks or a tanker truck for transportation to a treatment or disposal site; and
- tank leakage.

In general, flowback water is water and associated chemical constituents returning from the borehole during or proximate in time to hydraulic fracturing activities. Production brine, on the other hand, is fluid that returns from the borehole after completion of drilling operations while natural gas production is underway. The chemical characteristics and volumes of flowback water and production brine are expected to differ in significant respects."

"An uncontained and unmitigated surface spill could result in rapid contamination of a portion of a Primary or Principal aquifer."

"The wellbore being drilled, completed or produced, or a nearby wellbore that is ineffectively sealed, has the potential to provide subsurface pathways for groundwater pollution from well drilling, flowback or production operations. Pollutants could include: turbidity; fluids pumped into or flowing from rock formations penetrated by the well; and natural gas present in the rock formations penetrated by the well."

"These potential impacts are not unique to horizontal wells… The unique aspect of the proposed multi-well development method is that continuous or intermittent activities would occur over a longer period of time at any given well pad."

'Turbidity, or suspension of solids in the water supply, can result from any aquifer penetration (including monitoring wells, water wells, oil and gas wells, mine shafts and construction pilings) if sufficient porosity and permeability or a natural subsurface fracture is present to transmit the disturbance. The majority of these situations correct themselves in a short time."

"Sediment or Turbidity: Sediment laden, or turbid, water can increase the effective transportation of pathogens, serve as food for pathogens, promote the re-growth of pathogens in the water distribution system, and shelter pathogens from exposure to attack by disinfectants such as chlorine or ultraviolet light. The organic particles that are a cause of turbidity can combine with chlorine to create problematic disinfection by-products that are possible carcinogens and suspected by medical studies of increasing the risk of miscarriage."

“Fluids for hydraulic fracturing are pumped into the wellbore for a short period of time per fracturing stage, until the rock fractures and the proppant has been placed. For each horizontal well the total pumping time is generally between 40 and 100 hours. ICF International, under its contract with NYSERDA to conduct research in support of SGEIS preparation, provided the following discussion and analysis with respect to the likelihood of groundwater contamination by fluids pumped into a wellbore for hydraulic fracturing (emphasis added):

In the 1980s, the American Petroleum Institute (API) analyzed the risk of contamination from properly constructed Class II injection wells to an USDW due to corrosion of the casing and failure of the casing cement seal. Although the API did not address the risks for production wells, production wells would be expected to have a lower risk of groundwater contamination due to casing leakage. Unlike Class II injection wells which operate under sustained or frequent positive pressure, a hydraulically fractured production well experiences pressures below the formation pressure except for the short time when fracturing occurs. During production, the wellbore pressure would be less than the formation pressure in order for formation fluids or gas to flow to the well. Using the API analysis as an upper bound for the risk associated with the injection of hydraulic fracturing fluids, the probability of fracture fluids reaching a USDW due to failures in the casing or casing cement is estimated at less than 2 x 10-8 (fewer than 1 in 50 million wells). More recently, regulatory officials from 15 states have testified that groundwater contamination as a result of hydraulic fracturing, which includes this pumping process, has not occurred”

Gas migration

“As discussed above, turbidity is typically a short-term problem which corrects itself as suspended particles settle. The probability of groundwater contamination from fluids pumped into a properly-constructed well is very low. Natural gas migration is a more reasonably anticipated risk posed by high-volume hydraulic fracturing.”

“The 1992 GEIS…describes the following scenarios related to oil and gas well construction where natural gas could migrate into potable groundwater supplies:

Inadequate depth and integrity of surface casing to isolate potable fresh water supplies from deeper gas-bearing formations;

Inadequate cement in the annular space around the surface casing, which may be caused by gas channeling or insufficient cement setting time; gas channeling may occur as a result of naturally occurring shallow gas or from installing a long string of surface casing that puts potable water supplies and shallow gas behind the same pipe; and,

Excessive pressure in the annulus between the surface casing and intermediate or production casing. Such pressure could break down the formation at the shoe of the surface casing and result in the potential creation of subsurface pathways outside the surface casing. Excessive pressure could occur if gas infiltrates the annulus because of insufficient production casing cement and the annulus is not vented in accordance with required casing and cementing practices.”

"As explained in the 1992 GEIS, potential migration of natural gas to a water well presents a safety hazard because of its combustible and asphyxiant nature, especially if the natural gas builds up in an enclosed space such as a well shed, house or garage. Well construction practices designed to prevent gas migration would also form a barrier to other formation fluids such as oil or brine. Although gas migration may not manifest itself until the production phase, its occurrence would result from well construction (i.e., casing and cement) problems."

"Toxic Compounds:
Unfiltered drinking water supplies have a heightened sensitivity to chemical discharges as there is no immediately available method to remove contaminants from the drinking water source waters.

"Well pad containment practices and setbacks are likely to effectively contain most spills at those locations. There is a continuing risk, however, of releases from chemicals, petroleum products and drilling fluids from the well pad as a result of tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or improper operations. Spilled, leaked or released fluids could flow to a surface water body. The intensive level of trucking activity associated with high volume hydraulic fracturing, including the transport of chemical and petroleum products, presents an additional risk of surface water contamination due to truck accidents and associated releases. Given the topography of much of the NYC and Skaneateles Lake watersheds, many of the roadways are in immediate proximity to tributaries. Such proximity increases the risk that chemical and petroleum spills would not, or could not, be effectively intercepted before entering the drinking water supply."

"One acre of impervious surface is estimated to create the same amount of runoff as 16 acres of naturally vegetated meadow or forest."

"Similarly, the risks associated with high volumes of truck traffic transporting chemical and petroleum products associated with high-volume hydraulic fracturing is inconsistent with effective protection of an unfiltered drinking water supply. This is especially so, as a number of factors, discussed above, are already operating to stress the NYC and Syracuse source waters. This concern is exemplified by an extensive study by researchers from SUNY ESF and Yale published in 2008. This peer reviewed report concluded that the current rate of excavations and associated increases in impervious and less pervious surfaces within the NYC Watershed would likely result in the phosphorus impairment of all reservoirs over an approximate 20 year time frame. This report does not take into consideration the accelerated development associated with high-volume hydraulic fracturing."

"Accordingly, and for all of the aforementioned reasons, the Department concludes that high volume hydraulic fracturing operations within the NYC and Syracuse watersheds pose the risk of causing significant adverse impacts to water resources."

"Reference is made [] to ICF International's calculations of the rate at which fracturing fluids could move away from the wellbore through fractures and the rock matrix during pumping operations under hypothetical assumptions of a hydraulic connection. ICF's conclusion is that —hydraulic fracturing does not present a reasonably foreseeable risk of significant adverse environmental impacts to potential freshwater aquifers. Specific conditions or analytical results supporting this conclusion include: The developable shale formations are vertically separated from potential freshwater aquifers by at least 1,000 feet of sandstones and shales of moderate to low permeability;

The amount of time that fluids are pumped under pressure into the target formation is orders of magnitude less than the time that would be required for fluids to travel through 1,000 feet of low-permeability rock;

The volume of fluid used to fracture a well could only fill a small percentage of the void space between the shale and the aquifer;

Some of the chemicals in the additives used in hydraulic fracturing fluids would be adsorbed by and bound to the organic-rich shales;

Diffusion of the chemicals throughout the pore volume between the shale and an aquifer would dilute the concentrations of the chemicals by several orders of magnitude; and

Any flow of fracturing fluid toward an aquifer through open fractures or an unplugged wellbore would be reversed during flowback, with any residual fluid further flushed by flow from the aquifer to the production zone as pressures decline in the reservoir during production."

"The developable shale formations are vertically separated from potential freshwater aquifers by at least 1,000 feet of sandstones and shales of moderate to low permeability. Most of the bedrock formations above the Marcellus Shale are other shales. That shales must be hydraulically fractured to produce fluids is evidence that these rocks do not readily transmit fluids. The high salinity of native water in the Marcellus and other Devonian shales is evidence that fluid has been trapped in the pore spaces for a significant length of time, implying that there is no mechanism for discharge. As previously discussed, hydraulic fracturing is engineered to target the prospective hydrocarbon-producing zone. The induced fractures create a pathway to the intended wellbore, but do not create a discharge mechanism or pathway beyond the fractured zone where none existed before. The pressure differential that pushes fracturing fluid into the formation is diminished once the rock has fractured, and is reversed toward the wellbore during the flowback and production phases."

"Darcy's Law is a universally accepted scientific principle of hydrogeology. It states the relationship that explains fluid flow in porous media. Flow rate, Q, is calculated by Q=KA(Phigh-Plow)/µL where K= permeability, A= cross sectional area, P=pressure, µ=fluid viscosity and L=length of flow. The factor —Phigh-Plow describes a pressure differential, and Darcy‘s Law explains the relationship between pressure and fluid flow. "During hydraulic fracturing operations, the pressure in the well is greater than the pressure in the formation and drives the fluid and sand into the rock creating the induced fractures. If induced fractures do intersect an open fault or wellbore that diverts fluid from the target formation during pumping, this would be detected by required pressure monitoring during the fracturing process. Permit conditions will require pumping operations to cease if this occurs, until the anomalous condition is evaluated and addressed. Cessation of pumping will remove the pressure differential and stop further flow away from the target formation. Additionally, the force exerted by lithostatic pressure (i.e., the weight of overlying rocks) tends to close natural fissures at depth, so even when such fissures exist they are not necessarily transmissive. This is the reason that hydraulic fracturing requires the use of proppant to keep induced fractures open to transmit natural gas to the wellbore. Also, even if it is assumed that fractures in overlying strata are transmissive, there is no reason to believe that the fractures of different strata are aligned in a manner that would make hydraulic connections possible."

"Once pumping ceases and hydraulic fracturing is accomplished, the well is turned into the production system at the surface which is at a much lower pressure than the formation. Therefore gas flows to the well and the surface. At this point there is no pressure differential that would cause fluid to move in any direction other than towards the gas well."

"All of the above factors that inhibit vertical fracturing fluid migration would also inhibit horizontal migration beyond the fracture zone for the distances required to impact potable water wells in the Marcellus and other shales from high-volume hydraulic fracturing under the conditions specified by ICF. Because of regional dip, the geographic location of any target reservoir where it is more than 1,000 feet below the presumed base of fresh water would be at least several miles south of any location where water wells are completed in the same rock formation."

"Flowback water may be sent to POTWs. However, treatability of flowback water presents a potential environmental concern because residual fracturing chemicals and naturally-occurring constituents from the rock formation could be present in flowback water and have treatment, sludge disposal, and receiving-water impacts. Salts and dissolved solids may not be sufficiently treated by municipal biological treatment and/or other treatment technologies which are not designed to remove pollutants of this nature."

"The large volumes of return water from high-volume hydraulic fracturing combined with the diverse mixture of chemicals and high concentrations of TDS that exist in both flowback water and production water, requires that the permittee submit a headworks analysis specific to the parameters expected present in high-volume hydraulic fracturing wastewater including TDS and NORM,,"…

Methane Migration

"The dSGEIS explains that the potential migration of natural gas to a water well, which presents a safety hazard because of its combustible and asphyxiant nature, especially if the natural gas builds up in an enclosed space such as a well shed, house or garage, was fully addressed in the 1992 GEIS. Well construction associated with high-volume hydraulic fracturing presents no new significant adverse impacts with regard to potential gas migration. Gas migration is a result of poor well construction (i.e., casing and cement problems). As with all gas drilling, well construction practices mandated in New York are designed to prevent gas migration. Those practices would also minimize the risk of migration of other formation fluids such as oil or brine."

"The dSGEIS acknowledges that migration of naturally-occurring methane from wetlands, landfills and shallow bedrock can also contaminate water supplies independently or in the absence of any nearby oil and gas activities."

Fracture Fluid Migration

"The dSGEIS contains "analyses that demonstrate that no significant adverse impact to water resources is likely to occur due to underground vertical migration of fracturing fluids through the shale formations. The developable shale formations are vertically separated from potential freshwater aquifers by at least 1,000 feet of sandstones and shales of moderate to low permeability. In fact, most of the bedrock formations above the Marcellus Shale are other shales. That shales must be hydraulically fractured to produce fluids is evidence that these types of rock formations do not readily transmit fluids. The high salinity of native water in the Marcellus and other Devonian shales is evidence that fluid has been trapped in the pore spaces for hundreds of millions of years, implying that there is no mechanism for discharge of fluids to other formations."

"Hydraulic fracturing is engineered to target the prospective hydrocarbon-producing zone. The induced fractures create a pathway to the intended wellbore, but do not create a discharge mechanism or pathway beyond the fractured zone where none existed before. The pressure differential that pushes fracturing fluid into the formation is diminished once the rock has fractured, and is reversed toward the wellbore during the flowback and production phases. Accordingly, there is no likelihood of significant adverse impacts from the underground migration of fracturing fluids."

Liquid Waste Disposal

"No significant adverse impacts are identified with regard to the disposal of liquid wastes. Drilling and fracturing fluids, mud-drilled cuttings, pit liners, flowback water and produced brine, although classified as non-hazardous industrial waste, must be hauled under a New York State Part 364 waste transporter permit issued by the Department. Furthermore….any environmental risk posed by the improper discharge of liquid wastes would be addressed through the institution of a waste tracking procedure similar to that which is required for medical waste, even though the hazards are not equivalent."

"The disposal of flowback water could cause a significant adverse impact if the wastewater was not properly treated prior to disposal. Residual fracturing chemicals and naturally-occurring constituents from the rock formation could be present in flowback water and could result in treatment, sludge disposal, and receiving-water impacts. Salts and dissolved solids may not be sufficiently treated by municipal biological treatment and/or other treatment technologies which are not designed to remove pollutants of this nature."

"The potential for significant adverse environmental impacts from any proposal to inject flowback water from high-volume hydraulic fracturing into a disposal well would be reviewed on a site-specific basis with consideration to local geology (including faults and seismicity), hydrogeology, nearby wellbores or other potential conduits for fluid migration and other pertinent site-specific factors."

Flood plains

"The 1992 GEIS summarized the potential impacts of flood damage relative to mud or reserve pits, brine and oil tanks, other fluid tanks, brush debris, erosion and topsoil, bulk supplies (including additives) and accidents. Those potential impacts are equally applicable to high volume hydraulic fracturing operations. Severe flooding is described as one of the few ways that bulk supplies such as additives "might accidentally enter the environment in large quantities."

NORM (naturally occurring radioactive material)

"Gamma ray logs from deep wells drilled in New York over the past several decades show the Marcellus Shale to be higher in radioactivity than other bedrock formations including other potential reservoirs that could be developed by high-volume hydraulic fracturing. However, based on the analytical results from field-screening and gamma ray spectroscopy performed on samples of Marcellus Shale NORM levels in cuttings are not significant because the levels are similar to those naturally encountered in the surrounding environment. … the total volume of drill cuttings produced from drilling a horizontal well may be about 40% greater than that for a conventional, vertical well. For multi-well pads, cuttings volume would be multiplied by the number of wells on the pad. The potential water resources impact associated with the greater volume of drill cuttings from multiple horizontal well drilling operations would arise from the retention of cuttings during drilling, necessitating a larger reserve pit that may be present for a longer period of time, unless the cuttings are directed into tanks as part of a closed loop tank system."

(b) Impacts on Ecosystems and Wildlife

"The dSGEIS has been revised to expand the analysis of the potential significant adverse impacts on ecosystems and wildlife from high-volume hydraulic fracturing operations. Four areas of concern related to high-volume hydraulic fracturing are: (1) fragmentation of habitat; (2) potential transfer of invasive species; (3) impacts to endangered and threatened species; and (4) use of state-owned lands."

"The dSGEIS concludes that high-volume hydraulic fracturing operations would have a significant impact on the environment because such operations have the potential to draw substantial development into New York, which would result in unavoidable impacts to habitats (fragmentation, loss of connectivity, degradation, etc.), species distributions and populations, and overall natural resource biodiversity. Habitat loss, conversion, and fragmentation (both short term and long-term) would result from land grading and clearing, and the construction of well pads, roads, pipelines, and other infrastructure associated with gas drilling."

"The number of vehicle trips associated with high-volume hydraulic fracturing, particularly at multi-well sites, has been identified as an activity which presents the opportunity to transfer invasive terrestrial species. Surface water withdrawals also have the potential to transfer invasive aquatic species. The introduction of terrestrial and aquatic invasive species would have a significant adverse impact on the environment."

"… Given the level of development expected for multi-pad horizontal drilling, the dSGEIS anticipates that there would be additional pressure for surface disturbance on State lands. Surface disturbance associated with gas extraction could have an impact on habitats on State lands, and recreational use of those lands, especially large contiguous forest patches that are valuable because they sustain wide-ranging forest species, and provide more habitat for forest interior species."

"…Endangered and threatened wildlife may be adversely impacted through project actions such as clearing, grading and road building that occur within the habitats that they occupy. Certain species are unable to avoid direct impact due to their inherent poor mobility (e.g., Blanding's turtle, club shell mussel). Certain actions, such as clearing of vegetation or alteration of stream beds, can also result in the loss of nesting and spawning areas..."

"The development of Marcellus Shale gas will have a large footprint. In addition to direct loss of habitat, constant activity on each well pad from construction, drilling, and waste removal can be expected for 4 to 10 months, further affecting species. If a pad has multiple wells, it might be active for several years. "

"Habitat loss is the direct conversion of surface area to uses not compatible with the needs of wildlife, and can be measured by calculating the physical dimensions of well pads, roads, and other infrastructure. In addition to loss of habitat, other potential direct impacts on wildlife from drilling in the Marcellus Shale include increased mortality, increase of edge habitats, altered microclimates, and increased traffic, noise, lighting, and well flares."

"Habitat fragmentation from human infrastructure has been identified as one of the greatest threats to biological diversity. Research on habitat fragmentation impacts from oil and gas development specific to New York is lacking"

"Wetlands - State regulation of wetlands is described in Chapter 2. The 1992 GEIS summarizes the potential impacts to wetlands associated with interruption of natural drainage, flooding, erosion and sedimentation, brush disposal, increased access and pit location, and those potential impacts are applicable to high-volume hydraulic fracturing."

(c) Impacts on Air Resources

"As part of the Department's effort to address the potential air quality impacts of horizontal drilling and hydraulic fracturing activities in the Marcellus Shale and other low-permeability gas reservoirs, an air quality modeling analysis was undertaken by DEC's Division of Air Resources (DAR). The analysis identifies the emission sources involved in well drilling, completion and production, and the analysis of source operations for purposes of assessing compliance with applicable air quality standards."

(d) Greenhouse Gas Emission Impacts

"All operational phases of proposed well pad activities were considered, and resulting greenhouse gas (GHG) emissions determined in the dSGEIS. Emission estimates of carbon dioxide (CO_2) and methane (CH_4) are included as both short tons and as carbon dioxide equivalents (CO_2e) expressed in short tons for expected exploration and development of the Marcellus Shale and other low-permeability gas reservoirs using high-volume hydraulic fracturing. The Department not only quantified potential GHG emissions from activities, but also identified and characterized major sources of CO_2 and CH_4 during anticipated operations so that key contributors of GHGs with the most significant Global Warming Potential (GWP) could be addressed and mitigated, with particular emphasis placed on mitigating CH_4, with its greater GWP."

"The goal of this analysis is to characterize and present an estimate of GHG emissions for the siting, drilling and completion of 1) single vertical well, 2) single horizontal well, 3) four-well pad (i.e., four horizontal wells at the same site), and respective first-year and post first-year emissions of CO_2, and other relative GHGs, as both short tons and as carbon dioxide equivalents (CO_2e) expressed in short tons, for exploration and development of the Marcellus Shale and other low-permeability gas reservoirs using high volume hydraulic fracturing. In addition, the major contributors of GHGs are to be identified and potential mitigation measures offered".

Greenhouse Gases -

"The two most abundant gases in the atmosphere, nitrogen (comprising 78% of the dry atmosphere) and oxygen (comprising 21%), exert almost no greenhouse effect. Instead, the greenhouse effect comes from molecules that are more complex and much less common. Water vapor is the most important greenhouse gas, and CO_2 is the second-most important one. Human activities result in emissions of four principal GHGs: CO_2, CH_4, nitrous oxide (N_2O) and the halocarbons (a group of gases containing fluorine, chlorine and bromine). These gases accumulate in the atmosphere, causing concentrations to increase with time. Many human activities contribute GHGs to the atmosphere. Whenever fossil fuel (coal, oil or gas) burns, CO_2 is released to the air. Other processes generate CH_4, N_2O and halocarbons and other GHGs that are less abundant than CO_2, but even better at retaining heat."

Emissions from Oil and Gas Operations -

"GHG emissions from oil and gas operations are typically categorized into 1) vented emissions, 2) combustion emissions and 3) fugitive emissions. Below is a description of each type of emission. For the noted emission types, no distinction is made between direct and indirect emissions in this analysis. Further, this GHG discussion is focused on CO_2 and CH_4 emissions as these are the most prevalent GHGs emitted from oil and gas industry operations, including expected exploration and development of the Marcellus Shale and other low-permeability gas reservoirs using high volume hydraulic fracturing. Virtually all companies within the industry would be expected to have emissions of CO_2 - and, to a lesser extent, CH_4 and N_2O - since these gases are produced through combustion. Both CH_4 and CO_2 are also part of the materials processed by the industry as they are produced in varying quantities, from oil and gas wells. Because the quantities of N_2O produced through combustion are quite small compared to the amount of CO_2 produced, CO_2 and CH_4 are the predominant oil and gas industry GHGs."

Vented Emissions-
"Vented sources are defined as releases resulting from normal operations. Vented emissions of CH_4 can result from the venting of natural gas encountered during drilling operations, flow from the flare stack during the initial stage of flowback, pneumatic device vents, dehydrator operation, and compressor start-ups and blowdowns. Oil and natural gas operations are the largest human made source of CH_4 emissions in the United States and the second largest human-made source of CH_4 emissions globally. Given methane's role as both a potent greenhouse gas and clean energy source, reducing these emissions can have significant environmental and economic benefits. Efforts to reduce CH_4 emissions not only conserve natural gas resources but also generate additional revenues, increase operational efficiency, and make positive contributions to the global environment."

Combustion Emissions-
"Combustion emissions can result from stationary sources (e.g., engines for drilling, hydraulic fracturing and natural gas compression), mobile sources and flares. Carbon dioxide, CH_4, and N_2O are produced and/or emitted as a result of hydrocarbon combustion. Carbon dioxide emissions result from the oxidation of the hydrocarbons during combustion. Nearly all of the fuel carbon is converted to CO_2 during the combustion process, and this conversion is relatively independent of the fuel or firing configuration. Methane emissions may result due to incomplete combustion of the fuel gas, which is emitted as unburned CH_4. Overall, CH_4 and N_2O emissions from combustion sources are significantly less than CO_2 emissions."

Fugitive Emissions -
"Fugitive emissions are defined as unintentional gas leaks to the atmosphere and pose several challenges for quantification since they are typically invisible, odorless and not audible, and often go unnoticed. Examples of fugitive emissions include CH_4 leaks from flanges, tube fittings, valve stem packing, open-ended lines, compressor seals, and pressure relief valve seats. Three typical ways to quantify fugitive emissions at a natural gas industry site are 1) facility level emission factors, 2) component level emission factors paired with component counts, and 3) measurement studies. In the context of GHG emissions, fugitive sources within the upstream segment of the oil and gas industry are of concern mainly due to the high concentration of CH_4 in many gaseous streams, as well as the presence of CO_2 in some streams. However, relative to combustion and process emissions, fugitive CH_4 and CO_2 contributions are insignificant."

Emissions Source Characterization-
"Emissions of CO_2 and CH_4 occur at many stages of the drilling, completion and production phases, and can be dependent upon technologies applied and practices employed. Considerable research – sponsored by the API, the Gas Research Institute (GRI) and the EPA – has been directed towards developing relatively robust emissions estimates at the national level. The analytical techniques and emissions factors, and mitigation measures, developed by the these agencies were used to evaluate GHG emissions from activities necessary for the exploration and development of the

Marcellus Shale and other low-permeability gas reservoirs using high volume hydraulic fracturing."

"In 2009, NYSERDA contracted ICF International (ICF) to assist with supporting studies for the development of the SGEIS. ICF's work included preparation of a technical analysis of potential impacts to air in the form of a report finalized in August 2009.117 The report, which includes a discussion on GHGs, provided the basis for the following in-depth analysis of potential GHGs from the subject activity."

"ICF's referenced study identifies drilling, completion and production operations and equipment that contribute to GHG emission and provides corresponding emission rates, and this information facilitated the following analysis by identifying system components on an operational basis. As such, well site operations considered in the SGEIS were divided into the following phases for this GHG analysis:

- Drilling Rig Mobilization, Site Preparation and Demobilization;
- Completion Rig Mobilization and Demobilization;
- Well Drilling;
- Well Completion (includes hydraulic fracturing and flowback); and
- Well Production.

Transport of materials and equipment is an integral component of the oil and gas industry. Simply stated, a well cannot be drilled, completed or produced without GHGs being emitted from mobile sources. The estimated required truck trips per well and corresponding fuel usage for the below noted phases requiring transportation, except well production, were provided by industry."

"Drilling Rig Mobilization, Site Preparation and Demobilization

- Drill Pad and Road Construction Equipment
- Drilling Rig
- Drilling Fluid and Materials
- Drilling Equipment (casing, drill pipe, etc.)
- Completion Rig Mobilization and Demobilization
- Completion Rig

Well Completion

- Completion Fluid and Materials
- Completion Equipment (pipe, wellhead)
- Hydraulic Fracturing Equipment (pump trucks, tanks)
- Hydraulic Fracturing Water
- Hydraulic Fracturing Sand
- Flow Back Water Removal
- Well Production
- Production Equipment (5 – 10 Truckloads)"

"Three distinct types of well projects were evaluated for GHG emissions as follows:

- Single-Well Vertical Project;
- Single-Well Horizontal Project; and

- Four -Well Pad (i.e., four horizontal wells at the same site)."

Emission Rates

"Emission rates and calculations from the flaring of natural gas are presented in the previously mentioned 2009 ICF International report. In that report, it was determined that approximately 576 tons of CO_2 and 4.1 tons of CH_4 are emitted each day for a well being flared at a rate of 10 MMcf/d. ICF International's calculations assumed that 2% of the gas by volume goes uncombusted. ICF International relied on an average composition of Marcellus Shale gas to perform its emissions calculations."

Drilling Rig Mobilization, Site Preparation and Demobilization
"… approximately 15 tons of CO_2 emissions are expected from a mobilization of the drilling rig, including site preparation."

Completion Rig Mobilization and Demobilization
"..approximately 4 tons of CO_2 emissions may be generated from a mobilization of the completion rig."

Well Drilling
"Vertical wells may be drilled entirely using compressed air as the drilling fluid or possibly with air for a portion of the well and mud in the target interval. For horizontal wells, drilling activities would typically include the drilling of the vertical and lateral portions of a well using compressed air and mud (or other fluid) respectively. Regardless of the type of well, drilling activities are dependent on the internal combustion engines needed to supply electrical or hydraulic power to: 1) the rotary table or topdrive that turns the drillstring, 2) the drawworks, 3) air compressors, and 4) mud pumps. Carbon dioxide emissions occur from the engines needed to perform the work required to spud the well and reach its total depth. .. approximately 83 tons of CO_2 emissions per single vertical well would be generated as a result of drilling operations…CO_2 emissions of 194 tons and 776 tons for the drilling of a single horizontal well and four-well pad, respectively."

"…transportation related completion-phase emissions of CO_2 for a single vertical well is estimated at 12 tons. For the single horizontal well and the four-well pad[] transportation related completion-phase CO_2 emissions are estimated at 31 to 115 tons, respectively."

"Hydraulic fracturing operations require the use of many engines needed to drive the highpressure high-volume pumps used for hydraulic fracturing [].

"..approximately 54 tons and 325 tons of CO_2 emissions per well would be generated as a result of single vertical well and single horizontal well hydraulic fracturing operations, respectively."

"Subsequent to hydraulic fracturing in which fluids are pumped into the well, the direction of flow is reversed and flowback waters, including reservoir gas, are routed through separation equipment to remove excess sand, then through a line heater and finally through a separator to separate water and gas on route to the flare stack. Generally speaking, flares in the oil and gas industry are used to manage the disposal of hydrocarbons from routine operations, upsets, or emergencies via combustion. However, only controlled combustion events would be flared through stacks used during the completion phase for the Marcellus Shale and other low permeability gas reservoirs. A flaring period of 3 days was considered for this analysis for the vertical and horizontal wells respectively although the actual period could be either shorter or longer. "

"Initially, only a small amount of gas recovered from the well is vented for a relatively short period of time. If a sales line is available, once the flow rate of gas is sufficient to sustain combustion in a flare, the gas is flared until there is sufficient flowing pressure to flow the gas into the sales line. Otherwise, the gas is flared and combusted at the flare stack."

"…approximately 1,728 tons of CO2 and 12 tons of CH4 emissions are generated per well during a three-day flaring operation for a 10 Mmcf/d flowrate. "

"The CH4 emissions during flaring result from 2% of the gas flow remaining uncombusted. ICF computed the primary CO2 and CH4 emissions rates using an average Marcellus gas composition."

"The final work conducted during the completion phase consists of using a completion rig, possibly a coiled-tubing unit, to drill out the hydraulic fracturing stage plugs and run the production tubing in the well. Assuming a fuel consumption rate of 25 gallons per hour and an operating period of 24 hours, the rig engines needed to perform this work emit CO2 at a rate of approximately 4 tons per single vertical well and 7 tons per single horizontal well."

"After the completion rig is removed from the site, earth moving equipment would be transported to the site and the area would be reworked and graded, which adds another 9 tons of CO_2 emissions for either a one-well project or four-well pad."

Well Production

"Transportation needed to haul production equipment to a well site for a one-well project and a four-well pad results in first-year CO_2 emissions of approximately 3 tons and 11 tons, respectively."

"GHGs in the form of CO_2 and CH_4 are emitted during the well production phase from process equipment and compressor engines. Glycol dehydrators, specifically their vents, which are used to remove moisture from the natural gas in order to meet pipeline specifications and dehydrator pumps, generate vented CH4 emissions, as do pneumatic device vents which operate by using gas pressure. Compressors used to increase the pressure of the natural gas so that the gas can be put into the sales line typically are driven by engines which combust natural gas. The compressor engine's internal combustion cycle results in CO_2 emissions while compression of the natural gas generates CH_4 fugitive emissions from leaking packing systems. All packing systems leak under normal conditions, the amount of which depends on cylinder pressure, fitting and alignment of the packing parts, and the amount of wear on the rings and rod shaft. The emission []were used to calculate estimated emissions of CO_2 and CH_4 for each stationary source for a single vertical well, single horizontal well and four-well pad []"

"Based on the specified emissions rates for each piece of production equipment, the calculated annual GHG emissions [] show that the compressors, glycol dehydrator pumps and vents contribute the greatest amount of CH_4 emissions during [] this phase, while operation of pneumatic device vents also generates vented CH_4 emissions. The amount of CH4 vented in the compressor exhaust was not quantified in this analysis but, according to Volume II: Compressor Driver Exhaust, of the 1996 Final Report on Methane Emissions from the Natural Gas Industry, compressor exhaust accounts for —about 7.9% of methane emissions from the natural gas industry. "

"Therefore, GWP is a useful statistical weighting tool for comparing the heat trapping potential of various gases. For example, Chesapeake Energy Corporation's July 2009 Fact Sheet on greenhouse gas emissions states that CO_2 has a GWP of 1 and CH4 has a GWP of 23, and that this comparison allows emissions of greenhouse gases to be estimated and reported on an equal basis as CO_2.

.."for the purpose of assessing GHG impacts, each ton of CH_4 emitted is equivalent to 25 tons of CO_2. Thus, because of its recurring nature, the importance of limiting CH_4 emissions throughout the production phase cannot be overstated."

(e) Additional NORM Concerns

"Based upon currently available information it is anticipated that flowback water would not contain levels of NORM of significance, whereas production brine could contain elevated NORM levels. Although the highest concentrations of NORM are in produced waters, it does not present a risk to workers because the external radiation levels are very low. However, the build-up of NORM in pipes and equipment (pipe scale and sludge) has the potential to cause a significant adverse impact because it could expose workers handling (cleaning or maintenance) the pipe to increased radiation levels. Also, wastes from the treatment of production waters may contain concentrated NORM and, if so, controls would be required to limit radiation exposure to workers handling this material as well as to ensure that this material is disposed of in accordance with applicable regulatory requirements."

(f) Socioeconomic Impacts

"Using a low and average rate of development based on industry estimates, high-volume hydraulic fracturing will have a significant positive economic effect where the activity takes place. At the maximum rate of well construction, total direct construction employment is predicted to range from 4,408 construction jobs under the low development scenario to 17,634 jobs under the average scenario. An additional 29,174 jobs are predicted to result indirectly from the introduction of high-volume hydraulic fracturing statewide."

"There will also be positive impacts on income levels in the state as a result of high-volume hydraulic fracturing. When well construction reaches its maximum levels, total annual construction earnings are projected to range from $298.4 million under the low development scenario to nearly $1.2 billion under the average development scenario. Employee earnings from operational employment are expected to range from $121.2 million under the low development scenario to $484.8 million under the average development scenario in Year 30. Indirect employee earnings are anticipated to range from $202.3 million under the low development scenario to $809.2 million under the average development scenario in Year 30. The total direct and indirect impacts on employee earnings are projected to range from $621.9 million to $2.5 billion per year at peak production and construction levels in Year 30."

(g) Population Impacts

"While providing positive impacts in the areas of employment and income, high-volume hydraulic fracturing could cause adverse impacts on the availability of housing, especially temporary housing such as hotels and motels...certain regions "could [see] shortages of rental housing. "

"High-volume hydraulic fracturing would also bring both positive and negative impacts on state and local government spending. Increased activity will result in large increases in local tax revenues and increases in the receipt of production royalties but would also result in an increased demand for local services, including emergency response services."

(h) Visual, Noise and Community Character Impacts

"The construction of well pads and wells associated with high-volume hydraulic fracturing will result in temporary, but adverse impacts relating to noise. In certain areas the construction activity would also result in temporary visual impacts."

"The cumulative impact of well construction activity and related truck traffic would cause impacts on the character of the rural communities where much of this activity would take place."

(i) *Transportation Impacts*

"The introduction of high-volume hydraulic fracturing has the potential to generate significant truck traffic during the construction and development phases of the well. These impacts would be temporary, but the cumulative impact of this truck traffic has the potential to result in significant adverse impacts on local roads and, to a lesser extent, state roads where truck traffic from this activity is concentrated. It is not feasible to conduct a detailed traffic assessment given that the precise location of well pads is unknown at this time. However, such traffic has the potential to damage roads."

Total <u>One-Way</u>, Loaded Trips per Well Horizontal Drilling
Early development, heavy duty - 1,148
Early development, light duty - 831
Peak Well Pad Development heavy duty - 625
Peak Well pad development light duty - 795
Assumed a pipe line would be used for some water transport

Total Vehicle Trips = round trip combined early and development stages
Horizontal Heavy duty 3,950
Horizontal Light Duty 2,840

Vertical Heavy Duty 1,810
Vertical Light Duty 1,634

"Although truck traffic is expected to significantly increase in certain locations, most of the projected trips would be short. The largest component of the truck traffic for horizontal drilling would be for water deliveries, and these would involve very short trips between the water procurement area and the well pad. Since the largest category of truck trips involve water trucks (600 of 1,148 heavy truck trips) it is anticipated that the largest impacts from truck traffic would be near the wells under construction or on local roadways."

"Development of the high-volume hydraulic fracturing gas resource would also result in direct and indirect employment and population impacts, which would increase traffic on area roadways".

"As a result of the anticipated increase in heavy- and light-duty truck traffic, local roads in the vicinity of the well pads are expected to be damaged. Road damage could range from minor fatigue cracking (i.e., alligator cracking) to significant potholes, rutting, and complete failure of the road structure. Extra truck traffic would also result in extra required maintenance for other local road structures, such as bridges, traffic devices, and storm water runoff structures. Damage could occur as normal wear and tear, particularly from heavy trucks, as well as from trucks that may be on the margin of the road and directly running over culverts and other infrastructure that is not intended to handle such loads".

"...the different classifications of roads are constructed to accommodate different levels of service, defined by vehicle trips or vehicle class. Typically, the higher the road classification, the more stringent the design standards and the higher the grade of materials used to construct the road. The design of roads and bridges is based on the weight of vehicles that use the infrastructure. Local roads are not typically designed to sustain a high level of vehicle trips or loads and thus oftentimes have weight restrictions."

"When the cumulative and induced impacts of the total high-volume hydraulic fracturing gas development are considered, the resulting traffic impacts can be considerable. The principal cumulative traffic impacts would occur during drilling and well development. Impacts on the road, bridge, and other infrastructure would be primarily from the cumulative impact of heavy trucking."

"An increase in the amount of truck traffic, and vehicular traffic in general, traveling on both higher and lower level local roads would most likely increase the number of accidents and breakdowns in areas experiencing well development. These potential breakdowns and accidents would require the response of public safety and other transportation-related services (e.g., tow trucks). Local road commissions and the NYSDOT would also likely incur costs associated with operational and safety improvements."

Transportation of Haz. Materials.
"fracturing fluid is 98% freshwater and sand and 2% or less chemical additives. There are 12 classes of chemical additives that could be in the hazardous waste water being trucked to or from a location. Additive classes include: proppant, acid, breaker, bactericide/biocide, clay stabilizer/control, corrosion inhibitor, cross linker, friction reducer, gelling agent, iron control, scale inhibitor, and surfactant"

(j) Seismicity

"There is a reasonable base of knowledge and experience related to seismicity induced by hydraulic fracturing. Information reviewed indicates that there is essentially no increased risk to the public, infrastructure, or natural resources from induced seismicity related to hydraulic fracturing. The microseisms created by hydraulic fracturing are too small to be felt, or to cause damage at the ground surface or to nearby wells. Accordingly, no significant adverse impacts from induced seismicity are expected to result from high-volume hydraulic fracturing operations."

"The release of energy during hydraulic fracturing produces seismic pressure waves in the subsurface. Microseismic monitoring commonly is performed to evaluate the progress of hydraulic fracturing and adjust the process, if necessary, to limit the direction and length of the induced fractures."

"Seismic events that occur as a result of injecting fluids into the ground are termed —induced. There are two types of induced seismic events that may be triggered as a result of hydraulic fracturing. The first is energy released by the physical process of fracturing the rock which creates microseismic events that are detectable only with very sensitive monitoring equipment."

"Information collected during the microseismic events is used to evaluate the extent of fracturing and to guide the hydraulic fracturing process. This type of microseismic event is a normal part of the hydraulic fracturing process used in the development of both horizontal and vertical oil and gas wells, and by the water well industry. The second type of induced seismicity is fluid injection of any kind, including hydraulic fracturing, which can trigger seismic events ranging from imperceptible microseismic, to small scale, —felt events, if the injected fluid reaches an existing geologic fault. A —felt seismic event is when earth movement associated with the event is discernable by humans at the ground surface. Hydraulic fracturing produces microseismic events, but different injection processes, such as waste disposal injection or long term injection for enhanced geothermal, may induce events that can be felt... Induced seismic events can be reduced by engineering design and by avoiding existing fault zones.

"Induced seismic events caused by deep well fluid injection are typically less than a magnitude 3.0 and are too small to be felt or to cause damage. Rarely, fluid injection induces seismic events with moderate magnitudes, between 3.5 and 5.5, that can be felt and may cause damage. Most of these events have been investigated in detail and have been shown to be connected to circumstances that can be avoided through proper site selection (avoiding fault zones) and injection design."

"Hydraulic fracturing is a … process that involves injecting fluid under higher pressure for shorter periods than the pressure level maintained in a fluid disposal well. A horizontal well is fractured in stages so that the pressure is repeatedly increased and released over a short period of time necessary to fracture the rock. The subsurface pressures for hydraulic fracturing are sustained typically for one or two days to stimulate a single well, or for approximately two weeks at a multi-well pad. The seismic activity induced by hydraulic fracturing is only detectable at the surface by very sensitive equipment."

"Avoiding pre-existing fault zones minimizes the possibility of triggering movement along a fault through hydraulic fracturing. It is important to avoid injecting fluids into known, significant, mapped faults when hydraulic fracturing. Generally, operators would avoid faults because they disrupt the pressure and stress field and the hydraulic fracturing process. The presence of faults also potentially reduces the optimal recovery of gas and the economic viability of a well or wells."

"Injecting fluid into the subsurface can trigger shear slip on bedding planes or natural fractures resulting in microseismic events. Fluid injection can temporarily increase the stress and pore pressure within a geologic formation. Tensile stresses are formed at each fracture tip, creating shear stress. The increases in pressure and stress reduce the normal effective stress acting on existing fault, bedding, or fracture planes. Shear stress then overcomes frictional resistance along the planes, causing the slippage. The way in which these microseismic events are generated is different than the way in which microseisms occur from the energy release when rock is fractured during hydraulic fracturing."

"The amount of displacement along a plane that is caused by hydraulic fracturing determines the resultant microseism's amplitude. The energy of one of these events is several orders of magnitude less than that of the smallest earthquake that a human can feel. The smallest measurable seismic events are typically between 1.0 and 2.0 magnitude. In contrast, seismic events with magnitude 3.0 are typically large enough to be felt by people."

"There are no seismic monitoring protocols or criteria established by regulatory agencies that are specific to high volume hydraulic fracturing. Nonetheless, operators monitor the hydraulic fracturing process to optimize the results for successful gas recovery. It is in the operator's best interest to closely control the hydraulic fracturing process to ensure that fractures are propagated in the desired direction and distance and to minimize the materials and costs associated with the process."

"Hydraulic fracturing has been used by oil and gas companies to stimulate production of vertical wells in New York State since the 1950s. Despite this long history, there are no records of induced seismicity caused by hydraulic fracturing in New York State. The only induced seismicity studies that have taken place in New York State are related to seismicity suspected to have been caused by waste fluid disposal by injection and a mine collapse,”

“The seismic events induced at the Dale Brine Field were the result of the injection of fluids for extended periods of time at high pressure for the purpose of salt solution mining. This process is significantly different from the hydraulic fracturing process that would be undertaken for developing the Marcellus and other low-permeability shales in New York.”

“Wells are designed to withstand deformation from seismic activity. The steel casings used in modern wells are flexible and are designed to deform to prevent rupture. The casings can withstand distortions much larger than those caused by earthquakes, except for those very close to an earthquake epicenter. The magnitude 6.8 earthquake event in 1983 that occurred in Coalinga, California, damaged only 14 of the 1,725 nearby active oilfield wells, and the energy released by this event was thousands of times greater than the microseismic events resulting from hydraulic fracturing. Earthquake-damaged wells can often be re-completed. Wells that cannot be repaired are plugged and abandoned. Induced seismicity from hydraulic fracturing is of such small magnitude that it is not expected to have any effect on wellbore integrity.”

(k) Methane

“The presence of naturally-occurring methane in ground seeps and water wells is well documented throughout New York State. Naturally-occurring methane can be attributed to swampy areas or where bedrock and unconsolidated aquifers overlie Devonian-age shales or other gas-bearing formations. The highly fractured Devonian shale formations found throughout western New York are particularly well known for shallow methane accumulations. In his 1966 report on the Jamestown Aquifer, Crain explained that natural gas could occur in any water well in the area "which ends in bedrock or in unconsolidated deposits overlain by fine-grained confining material. Depth is not of primary importance because pockets of gas may occur in the bedrock at nearly any depth." Upper Devonian gas bearing rocks at or near the surface extend across the southern tier of New York from Chautauqua and Erie Counties, east to Delaware and Sullivan counties”

“Early explorers and water well drillers in New York reported naturally occurring methane in regions not then associated with natural gas well drilling activity. “Methane can occur naturally in water wells and when it does, it presents unique problems for water well drilling contractors. The major concern relates to flammable and explosive hazards associated with methane.” Gas that occurs naturally in shallow bedrock and unconsolidated sediments has been known to seep to the surface and/or contaminate water supplies including water wells. Often landowners are not aware of the presence of methane in their well. Methane is a colorless, odorless gas, and is generally considered non-toxic but there could be an explosive hazard if gas is present in significant volumes and the water well is not properly vented.”

“The existence of naturally occurring methane seeps in New York has been known since the mid 1600s… More recent studies and investigations have provided other evidence of naturally occurring methane in eastern New York. A private well in Schenectady

County was gaged at 158 MMcf/d of natural gas by the Department in 1965. The well provided natural gas for the owner's domestic use for 30 years. In 1987 the Times Union reported that contaminants, including methane, were found in well water in the Orchard Park subdivision near New Scotland, Albany County. Engineers from the Department reported the methane as "natural occurrences found in shale bedrock deposits beneath the development." Ten years later, in 1997, a Saratoga Lake-couple disclosed to a news reporter the presence of methane gas in their water well. The concentration of gas in the well water was concentrated enough for the owners to ignite the gas from the bathtub faucet. According to a September 22, 2010 article in the Daily Gazette, water wells in the Brown Road subdivision, Saratoga County became contaminated with methane gas when water wells were "blasted" (fractured) to reach a greater supply of water."

> "Methane contamination of groundwater is often mistakenly attributed to or blamed on natural gas well drilling and hydraulic fracturing. There are a number of other, more common, reasons that well water can display sudden changes in quality and quantity. Seasonal variations in recharge, stress on the aquifer from usage demand, and mechanical failures are some factors that could lead to degradation of well water. "

A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development, New York State Department of Health, December 2014 [23]

The New York State (NYS) Department of Health (DOH) recently released its Public Health Review of HVHF for Shale Gas recommending that HVHF should not proceed in NYS.

The task as described by NYS Acting Commissioner of Health, Howard A. Zucker, M.D., J.D., who assumed responsibility of the report when the previous commissioner left, was to "consider, more broadly, the current state of science regarding HVHF and public health risks".

More than 20 DOH Senior Research Scientists, Public Health Specialists, and Radiological Health Specialists contributed to the review, under the direction of the former and acting Commissioners of Health. In addition to evaluating published literature, Commissioners and DOH staff held multiple discussions and meetings with public health and environmental authorities in several states to understand their experience with HVHF. The Commissioners also met with researchers from academic institutions and government agencies to learn more about planned and ongoing studies and assessments on the public health implications on HVHF.

The review objectives consisted of the following:

1. An evaluation of the emerging scientific information on environmental public health and community health effects;
2. An analysis of whether such information was sufficient to determine the extent of potential public health impacts of HVHF activities in New York State; and
3. Whether existing mitigation measures implemented in other states are effectively reducing the risk for adverse public health impacts.

The DOH reviewed whether the following may result in adverse public health outcomes:

- HVHF activities which result in human exposure to: contaminants in air or water and naturally occurring radiological materials; and
- The effects of HVHF operations such as truck traffic, noise, and social changes on communities.

The following is a recap of the major findings:

Air Impacts: Air impacts discussed include evidence of uncontrolled methane leakage, emissions of other VOCs, and particulate matter from well pads and natural-gas infrastructure; heavy vehicle traffic and trucks idling at well pads; intermittently high dust and benzene concentrations, sometimes observed at distances of at least 625 feet from the center of the well pad and the potential for these emissions to contribute to community odor problems, respiratory health impacts such as asthma exacerbations, and longer-term climate change impacts from methane accumulation in the atmosphere.

Water-Quality Impacts: Studies have found evidence for underground migration of methane associated with faulty well construction; groundwater contamination clusters that the authors determined were due to gas leakage from intermediate-depth strata through failures of annulus cement, faulty production casings and underground gas well failure; additional sources of potential water contamination including surface spills and inadequate treatment and disposal of radioactive wastes; evidence for stray gas contamination, surface water impacts and the accumulation of radium isotopes in some disposal and spill sites; and, chemical signals of brine from deep shale formations in overlying groundwater aquifers.

Seismic Impacts: Recent evidence from studies in Ohio and Oklahoma suggest that HVHF can contribute to the induction of earthquakes during fracturing, raising new concerns about HVHF.

Community Impacts: Concerns are being raised in communities where HVHF has increased rapidly which are consistent with historical examples of the negative impact of rapid and concentrated increases in extractive resource development. These concerns include: interference with quality of life (noise, odors), overburdened transportation and health infrastructure, and disproportionate increases in social problems, particularly in small isolated rural communities where local governments and infrastructure tend to be unprepared for rapid changes.

THE DOH report cites a recent study from Pennsylvania which indicates automobile and truck accident rates in 2010-2012 from counties with heavy HVHF activity were between 15% and 65% higher than accident rates in counties without HVHF. Rates of traffic fatalities and major injuries were higher in 2012 in heavy drilling counties in southwestern PA compared to non-drilling counties.

Health Outcomes near HVHF Activity: One peer review study and one university report have presented data indicating statistical associations between some birth outcomes (low birth weight and some congenital defects) and residential proximity of the mother to well pads during pregnancy. Proximity to higher density HVHF well pad development was associated with increased incidence of congenital heart defects and neural-tube defects in one of the studies.

> Several published reports present data from surveys conducted among residents living near HVHF activities. Complaints commonly included skin rash or irritation, nausea or vomiting, abdominal pain, breathing difficulties or cough, nosebleeds, anxiety/stress, headache, dizziness, eye irritation and throat irritation in people and farm animals within proximity of natural gas development.
>
> Federal investigators have reported sub-standard work practices and deficient operational controls at well pads that contributed to elevated crystalline silica exposures among workers during HVHF operations. The DOH suggests residents living close to HVHF activities could experience similar exposures.

The DOH report describes numerous studies and findings but consistently raises concerns about the strength of the study's conclusions. According to the DOH, systematic, comprehensive, long-term, longitudinal studies that could contribute to the understanding of the complex relationships of HVHF and public health are needed. Several studies are underway and are described in the DOH report, many of which will not be completed for several years.

In the cover letter, Dr. Zucker states

> "As with most complex human activities in modern societies, absolute scientific certainty regarding the relative contributions of positive and negative impacts of HVHF on public health is unlikely to ever be attained. In this instance, however, the overall weight of the evidence from the cumulative body of information contained in this Public Health Review demonstrates that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health. Until the science provides sufficient information to determine the level of risk to public health from HVHF to all New Yorkers and whether the risks can be adequately managed, DOH recommends that HVHF should not proceed in NYS."

Scientific studies reporting relationships between HVHF and public health outcomes were the main focus of the DOH evaluation. Review letters with valuable input from the Health Specialists are included in the report. Other relevant literature, focused on HVHF and effects on environmental media, was also reviewed. The report includes 65 pages of varied and relevant abstracts.

A strong partnership between the DOH, NYS DEC and local government bodies is emphasized throughout the Health Specialists' comments.

Jackson, R.E. et al. (2013, July-August). Groundwater Protection and Unconventional Gas Extraction: The Critical Need for Field-Based Hydrogeological Research. Groundwater, 51, 488-510. [(24)]

R.E. Jackson outlines the critical need for field-based hydrogeologic research in response to activities associated with unconventional gas extraction. Recent advances in directional drilling technology permits up to 20 horizontal wells to be drilled from a single well pad. Deep and long horizontal wells, up to 9,000 feet in horizontal length combined with multistage hydraulic fracturing can now exploit relatively thin formations containing unconventional hydrocarbons resources. This ability has increased the supply of natural gas and gas use in North America.

Public concerns and moratoria imposed by some states and countries are pending further understanding of the environmental and public health impacts. The report outlines the nature of HVHF activities, potential shallow contamination pathways and factors leading to aquifer vulnerability. Key points are summarized below.

The author emphasizes that many problems are not associated only with unconventional drilling, but conventional drilling techniques too. Hydraulic fracturing in vertical/conventional boreholes has been used since the 1940's.

Unconventional drilling requires substantially more hydraulic fracturing fluid injection volumes. Because water can imbibe into the shale formation, non-aqueous based fracturing fluids provide an alternative. HVHF involves the injection of fluids (gas, liquid, foams) and a mix of additives adding elevated pressures through various stages of fracking.

Fractures develop perpendicular to the orientation of least possible stress, sometimes preferentially opening existing fractures. While pre-existing fractures and faults have some influence on fracture propagation, overall trajectory is oriented perpendicular to least possible stress. Most plays in North America are deeper than 1 kilometer (3,280 feet), though a few shallower are exploited. Empirical data suggest horizontal fractures dominate in stimulation conducted shallower than 450 meters (1,476 feet) while vertical fractures develop below 600 meters (1,968 feet). At shallow depth the least principal stress is vertical due to the erosion of overburden in sedimentary basins. Fracture growth monitoring techniques suggest induced vertical fracture heights do not exceed tens and hundreds of feet (refer to the article for details regarding technique and potential study biases). Minimal separation distances of 600 meters (1,968) between the target formation and overlying freshwater aquifer were recommended with caution that each unique geologic area should be investigated.

Contaminants of concern including methane and the chemical composition of fracking fluids and natural waters was addressed with an emphasis on migration pathways described in previous sections of this report. Hydrogeologic conditions, gas migration processes and leakage pathways are often based on estimates which the author recognizes as a significant science data gap.

The majority of examples of shallow groundwater contamination results from historically persistent problems with fluid containment at the surface. Surface spills often involve saline contamination, metals, Naturally Occurring Radioactive Materials (NORMs) and hydraulic fracturing chemicals infiltrating or overflowing holding ponds.

The understanding of gas migration through existing faults and fractures is based on limited information according to the author. The term microseepage is used and it is explained that seepage is slow enough that petroleum accumulations can exist for geologic time. The author reports that there is "no evidence that fracture propagation "out of zone" has occurred from deep reservoirs to shallow aquifers and that there is a low probability of shallow groundwater contamination through upward propagation of fractures.

The importance of widely accepted methodology for monitoring is emphasized including fingerprinting techniques (as for biogenic versus thermogenic methane). The hydrogeologic community has expertise studying fate and transport of relevant chemicals in groundwater including attenuation by dispersion, sorption and biodegradation (of brine, salts and aromatic hydrocarbons). There is little or no peer-reviewed and public data regarding groundwater occurrence and fate and transport of other anthropogenic chemicals used in unconventional natural gas production such as glycols, amines, metal complexes used as corrosion prohibitors, proprietary chemicals or metabolites or degradates that may form from these chemicals such as acrylamide. Peer review and monitoring data is sparse and generally related to spill incidents.

To support sustainable development of unconventional gas and protection of groundwater resources the author recommends two areas of hydrogeologic research to address science gaps:

1.) The characterization of the background or baseline conditions (including groundwater flow, geochemical and isotropic characterization, and gas pressure in shallow groundwater) and,

2.) Field experiments and studies to understand better the processes by which natural gas, saline formation waters and fracturing chemicals may invade and contaminate shallow groundwaters and then be remediated where necessary.

Baseline groundwater quality mapping is outlined. Refer to the original article for additional details.

Water Resource Impacts during unconventional shale gas development: The Pennsylvania Experience, by Susan L. Brantley, 2014. [(4)]

Based on a review of publicly available database resources, the author of *Water Resource Impacts during unconventional shale gas development: The Pennsylvania Experience*, Susan L. Brantley found limited evidence of contamination of surface water or groundwater in Pennsylvania (PA). [(4)] The question is whether this is because incidents are rare and are diluted quickly, or the studies are being hindered. There is a reported lack of information about the location and timing of incidents, a tendency not to release water quality data due to confidentiality or liability issues, a sparseness of sample data or sensor for the analytes of interest, the presence of pre-existing water impairments that make it difficult to determine potential impacts from shale gas activity and finally, the fact that sensors can malfunction or drift.

PA maintains a database of oil & gas well violations. In 2005 there were approximately 8 wells drilled and by November of 2013, there were 7,234 wells drilled in the Marcellus Shale in Pennsylvania. One-fifth of the wells received at least one, non-administrative Notice of Violation (NOV). 3.4% were issued NOVs due to well construction issues, 0.24% of wells were issued violations for methane migration into groundwater. Between 2008 and 2012, 161 of the 1,000 complaints received by the State implicated oil and gas activities. Natural gas was reported for 56% of the wells and brine salt for 14% of the properties. Other properties were impacted by sediments, turbidity and/or drill cuttings. No cases of subsurface transport of fracking or flow back fluids to water supplies were documented.

Some contaminants from the brine are common in natural waters such as sodium, calcium and chloride. Strontium, barium and bromide are more specific to Marcellus waters. Detections of bromide in streams in southwestern PA were attributed to permitted discharges from municipal or industrial wastewater treatment plants before the practice was banned in 2011. Drinking water problems that were determined by the regulator to be attributed to oil and gas wells in the area peaked around 2010 and spill rates peaked through 2012.

Surface leakage into bedrock fractures poses a high risk of contaminant migration to groundwater. Well pad construction often leads to excavation and exposure of bedrock fractures and pollution incidents at the well pad are "not uncommon". This migration path has a greater likelihood of impacting groundwater than upflow from thousands of feet of geologic media.

According to the author, only two incidents nationwide, one in West Virginia in 1987 and one in Pavilion Wyoming, have been reported where fracture fluids have allegedly entered groundwater or drinking water through wells or geologic media in the subsurface. Both incidents were controversial and neither incident have been reported in the peer-reviewed literature according to the author.

Casing leaks, cementation problems and construction problems associated with the oil and gas wells is an area of concern. A review of well records by others from 2005-2013 concluded that 219 out of 6,466 wells received NOVs for well construction problems. The rate of well problems (3.4%) is within the range of newly constructed wells that require additional "workover" due to the surface string to pass pressure testing. Nonetheless, the author reports that only 16 wells received NOVs for methane migration into groundwater. Well construction issues can be due to improper design and construction due to lack of understanding of the local geology. Poor cement development can result in shrinkage, channeling and high cement permeability that can result in oil and gas leaks along the casing and potential risk to water supplies.

Although incidents of methane migration due to shale gas activity have been identified, according to the author, methane is also present naturally due to both high-temperature maturation of organic matter at depth (thermogenic) and low-temperature bacteria processes (biogenic). Regardless of the source, methane will migrate upward through faults and along fractures from depth or laterally from swamps or glacial till. Faults will channelize gas through seeps in valley floors or wells. Methane can also be derived from anthropogenic sources such as landfills and gas pipelines. If methane enters wells as a solute it will off gas due to its low solubility and it is not regulated as a health hazard. However, if it accumulates at high enough concentrations, it can cause an explosion.

Though generally considered minor and easy to repair, at least one (often cited) incident attributed to gas wells in the Marcellus lead to contamination of 18 water supply wells and one well in Dimock, PA exploded.

The author cited two studies of methane in groundwater both completed in 2011 one by Osborn, et al., and another by Molofsky et al. Osborn conducted a study of 60 water wells and concluded that the average methane concentration (19.2 mg/L) was higher when sampled within 1 kilometer (km) of active Marcellus gas wells. However, 85% of the wells had detectable methane regardless of the proximity to gas wells. The study also found that the methane present in wells within 1 km of Marcellus had higher ^{13}C concentrations as expected for thermogenic gas. Molofsky, sampling >1,700 water wells found that 78% of the wells sampled contained detectable methane, however, those researchers concluded that the topographic position, rather than distance to gas wells was a greater predictor of the presence of elevated methane. Using samples collected from PA DEP and Cabbot Oil & Gas Corp., asserted that the isotopic signatures determined by Osborn to be of the Marcellus where less thermally mature and were from a more shallow formation.

In another regional comparison the author notes the rate of methane occurrence in the area studied by Osborn and Molofsky (85%) is significantly higher than in a wider regional area (24%) that includes southwest PA where pre- and post-drilling concentrations were statistically identical. Concluding that the geological regime in northern PA is conducive to stray gas migration. Additional debate regarding stray methane gas continues.

In addition to methane seepage, several Marcellus Shale wells have experienced blowouts during fracturing operations. The blowouts were attributed to mechanical or human error and led to uncontrolled releases of fracturing fluids requiring emergency response to shut the well. The blowouts occurred in two PA counties, were widely reported and resulted in significant fines.

Another type of incident reported by the author occurs when new shale gas well interconnects with an orphaned gas well or oil well that was never properly sealed. In PA, there is an estimated 350,000 oil and gas wells drilled since the first commercial well was drilled in the state in 1859. Over 200,000 of the wells were drilled before record keeping was required in 1955 and the locations are unknown. They were likely never sealed and may leak to the atmosphere, surface water or groundwater. In one case cited by the author, drilling one well (in June, 2012) caused methane to discharge from a nearby abandoned well (known as the Butters' Well), from a nearby private water well, from French lick Creek, and from a seismic borehole. The methane discharge in the Butters' Well reached >9 meters in the air. Residents were evacuated within a mile of the well. It was not determined how the methane migrated toward the wells, borehole and surface water, but drilling operations may have promoted migration along a fault. To reduce gas pressure, the PA DEP worked with the driller to flare off nearby Marcellus wells to reduce subsurface gas pressure. In addition, the Butters' well was sealed with cement and packers.

Events like this are becoming a greater concern as drilling in PA progresses to northwestern PA were the older wells were drilled. Currently drillers are not required to locate or seal wells prior to drilling, although it is in their best interest to do so.

Trucking accidents, well blowouts or leaking tanks, valves, or pipes have resulted in the release of fuels, fracturing chemicals, produced fluids, hydrostatic test water, sediments and drill cuttings or muds into

PA water.   These results often result in localized impacts to soil, sediments and/or groundwater that requires removal, remediation and monitoring.

To date, according to the author and based on sometimes limited online data maintained by the PA DEP, at least 32 spills, >400 gallons have occurred. This is based on 7,000 spudded (started) wells or 4,000 wells completed. Of spills >400 gal. 9 were brine (flowback or produced waters), 9 were drilling muds/fluids, 7 were gel or fracking fluids, 5 were hydrostatic test waters or sediments, 2 were unknown in nature and 1 was diesel fuel. The number of spills reported per year has generally increased since 2008 even though the new wells spudded per year and contamination cases per year have decreased since the 2010-2011 time period. The author suggests this may be because the number of wells completed (versus spudded) is still increasing.

In the Appalachian basin, Na and Cl are the most concentrated constituents in the flowback/production fluids and are the most likely contaminants to be detected in PA waters. Other major ions are calcium and magnesium. Some waters were partially treated at a wastewater treatment plant prior to being discharged to surface waters. This practice has been discouraged by PA DEP since 2011. The industry now increasingly recycles. PA DEP records indicate that approximately 87% of flow back and produced fluids were recycled in 2012 and continued through the end of the study, June, 2013.

One of the signature solutes for the Marcellus is bromide (Br^-). As of 2010, PA waterways in counties that have shale gas development, bromide concentrations were reported at more than 3 standard deviations above average. The author notes that the before and after data may be from differing water ways. The possibility that bromide has increased has significant health implications. Concentrations above 100 ug/L in source waters for publicly owned treatment works can lead to formation of bromine in the presence of free chlorine (a common disinfectant at treatment plants). Bromine can react with organic matter to form brominated THMs which have been linked with cancers and other concerns. In 2010, the Pittsburgh Water and Sewer Authority observed that the concentrations of total THMs and relative fraction of brominated THMs increased in its finished water. It was concluded that he increase was due to elevated Br in the Allegheny River source waters, and that most of the Br in the river derived from industrial wastewater treatment plants that were permitted to release wastewaters from Marcellus shale and conventional oil and gas wells. Additional observations led the PA DEP to impose a voluntary ban in April 2011 on discharge of unconventional shale gas brine through POTW and IWTPs into streams.

Total suspended solid (TSS) concentrations may increase as a result of land disturbance from well pad and pipeline construction. Drilling muds and cuttings may retain trace components of black shale or brine including metals such as barium and strontium, NORM and pyrite. Some of these materials are toxic in themselves. Pyrite can also oxidize and form sulfuric acid, thereby reducing pH and releasing metals. Sedimentation can cause excess runoff and sedimentation which is harmful to river ecosystems, especially in sensitive headwater streams.

The author reports that it takes on average 400,000 gallons of water per 500 ft of well bore for the Marcellus Shale and ranges from 4-5 million gallons per well over a 2-5 day period with about 10% of this returning as flowback. Water is typically supplied by lakes and streams but can also be extracted from groundwater. Water withdrawals may impact long-term ecological impacts in some areas. Changing the flow of streams can result in changes in water temperature, sediment transport, and channel shape all of which can adversely affect the river biota. The extraction of a volume of water can have a larger impact on a stream in low flow conditions. Low stream flow can impact municipal and industrial water needs, recreation and aquatic life. Best management practices include limiting withdrawals to periods of high flow and utilizing multiple sources.

Overall the author concluded that minor violations and temporary problems were reported, but that the "fast" shale-gas start may have led to relatively few environmental incidents of significant impact compare to the number of wells drilled, however, the impact remains difficult to assess due to the lack of transparent and accessible data.

Impact of Shale Gas Development on Regional Water Quality, R. D. Vidic, et al., 2013 [(7)]

The author explains that methane is not regulated in drinking water in the U.S., since it does not readily dissolve in water, it is not considered a health hazard with respect to ingestion. However, when present, methane can be oxidized by bacteria, resulting in oxygen depletion. Low oxygen can result in increased solubility of elements such as arsenic and iron. Additionally, anaerobic bacteria that may proliferate under such conditions may reduce sulfate to sulfide, creating water and air quality issues. When methane degasses it explodes in extreme cases. Therefore, the U.S. Department of the Interior recommends a warning if water contains 10 mg/L of CH_4 and immediate action if concentrations reach 28 mg/L. Methane concentration above 10 mg/L indicate that accumulation of gas could result in an explosion.

As natural gas moves in the subsurface, the author explains, it can be partially oxidized, mixed with other gases, or diluted along flow paths. To determine its provenance, a "multiple lines of evidence approach" must be pursued. Researchers measure the presence of other hydrocarbons as well as the isotopic signatures of H_20 in C in the water or gas. Thermogenic gas in general has more ethane and a higher $^{13}C/^{12}C$ ratio than that of biogenic gas. Stable isotopes in thermogenic gas may sometimes even yield clues about which shale was the source of the gas."

Although understanding the source may lead to solutions to the problem, as the author points out, the source does not affect liability because gas companies are responsible if it can be shown that any gas, not just methane, has moved into t water well because of shale-gas development. For example, drilling can open surficial fractures that allow preexisting native gas to leak into water wells. This means pre and post data is necessary to determine "culpability".

The author describes issues regarding well casing which contribute to gas migration. Well casing protects the freshwater zones and the surrounding environment from the inside of the well. Stray gas can become an issue when the integrity of the well bore becomes an issue. One of the primary causes of gas migration is related to the upper portion of the wellbore when it is drilled into the a rock formation that contains preexisting high pressure gas which can have destructive effects on the integrity of the outer cement annulus such as the formation of micro channels. Temperature surveys can be performed to test the cement after it is set to confirm that the cement is present behind the casing. Acoustic logging tools are also available. Proper cement design and mud removal are essential in over pressurized gas zones. If the hydrostatic pressure of the cement column is not greater than the gas-bearing formation pressure, gas can invade the cement before it sets. Or, if the pressure is too high, then the formation can fracture and slurry will be lost to the formation. Even if correct, the gas from the formation can invade the cement as it hardens. The slurry must be designed to minimize this stage and the loss of slurry from the slurry to the formation. The mud needs to be thoroughly cleaned from the casing before cementing or mud channels can form through the central portion of the annulus or between the cement and the formation interface. Even if properly cleaned and the cement is placed properly, shrinkage or cracking can occur during the life of the well. Varying drilling conditions and geology affect the risk.

The projected water required for drilling in the Marcellus shale is 18.7 million gallons per day as of 2013. This constitutes just 0.2% of the total annual water withdrawals in PA. Other areas are similarly low. Local impacts may be felt during periods of drought. Best management practices determining when and where water is extracted are recommended.

This author estimates the volume of water from horizontal wells in PA ranges from 9 to 53% with an average of 10%. Two key unanswered questions is what happens to the fracturing fluid that is not recovered during the flowback period, and whether this fluid could eventually contamination drinking water aquifers.

#1 The analyses of the Marcellus shale well logs indicate that there is very little water in the low permeability shale and much of the water is absorbed into the shale. The author indicates that some induced fractures have extended as much as 460 meters above the top of some hydraulically fractured shales

#2 Fracturing fluid could migrate along abandoned and improperly plugged oil and gas wells through an inadequately sealed annulus between the well bore and casing

#3 Fracture fluid could migrate through natural or induced fractures outside the target formation. Some out-of-formation fractures have been documented to extend as much as 460 meters above the top of some hydraulically fractured shales but these are typically still 1.6 km or more below freshwater aquifers.

Wastewater generated from drilling activities in the Marcellus Shale are a challenge since it is the second saltiest and most radioactive of all the sedimentary basins in the U.S., the author reports. Marcellus Shale wells generate one third of the wastewater per unit volume of gas produced. Because of the high volume, high concentration of dissolved solids and complex composition of the water which included organic and radioactive components, storing the water in large pits at the well site is causing concern due to the risk of release to surface or groundwater. The majority of wastewater from oil and gas production in the U.S. is disposed through deep underground injection wells. In PA, as of 2013, there were only 5 operating. Permitting of additional wells will be costly and take time. Transporting wastes to West Virginia and Ohio is costly. The dominant wastewater disposal method in PA currently is reuse. Wastewater is impounded at the surface and used directly or after dilution or pretreatment. Drillers in the area are concerned about the quality of the water being reused and the possible precipitation of $BaSO_4$ and to a lesser extent $SrSo_4$ and $CaCO_3$ into the shale formation and reaction of the wastewater with fracturing fluid constituents. The wastewater reuse program is consider a short term solution and is feasible only when there is a net consumption of water which decreases as the well field matures.

(3) A recommendation as to whether the prohibition on hydraulic fracturing under 29 V.S.A § 571 should be repealed.

Based on the language in Bill H.464 which passed the Vermont House and Senate, when hydraulic fracturing can be conducted without risk of contamination to the groundwater of Vermont, the general assembly should repeal the prohibition on hydraulic fracturing for oil and natural gas recovery.

At the present time the Agency of Natural Resources –Department of Environmental Conservation does not have sufficient evidence that hydraulic fracturing for oil and gas can be conducted without risk of contamination to the groundwater of Vermont. In fact, the evidence suggests that the practice of hydraulic fracturing has significant potential to cause both groundwater contamination and degradation of air quality, if any of the risks are improperly managed or controlled. Therefore, it is our recommendation that the prohibition on hydraulic fracturing for oil and natural gas recovery be continued.

D. Rule Amendments

In accordance with Bill H.464 Section 5, on or before July 15, 2015, the Secretary of Natural Resources shall amend the rules regulating the discharge of waste into an injection well, including those discharges into an injection well for oil and gas recovery for which the agency of natural resources has jurisdiction, in order to update the rules to reflect existing requirements under federal and state law and to address practices not contemplated by the existing rules. In amending the rules regulating the discharge of waste into an injection well, the agency of natural resources shall provide that no permit shall be issued under 10 V.S.A. Chapter 47 for a discharge of waste into an injection well when such a discharge would endanger an underground source of drinking water.

The Underground Injection Control Regulations under Chapter 11 of the Environmental Protection Rules were amended and became effective October 29, 2014. The following prohibitions pertaining to the potential for hydraulic fracturing for the purposes of oil and gas recovery were included in the Rule Amendment:

> Under *Subchapter 3 Prohibitions; Permit Required; Exemptions*, *Section §11-301 Prohibitions*
>
> (a) No person shall construct, operate, maintain, or convert any Class I, Class II, or Class III well.
>
> (c) No person shall construct, operate, maintain, modify, or convert a Class V well that receives waste from the location within a facility or business where the following occurs:
>
> (14) Hydraulic fracturing used to extract natural gas or oil.

Class II Waste injection wells are used for the injection of liquid wastes generated through hydraulic fracturing of oil and gas bearing formations and are now prohibited in the State of Vermont.

Class V wells are prohibited at any site involved in hydraulic fracturing for oil and gas.

E. Additional Recommendations

Once released, the EPA report *Impacts of Hydraulic Fracturing on Drinking Water Resources* should be reviewed and summarized in a supplement to this report. A new statement regarding the prohibition of hydraulic fracturing, considering the new EPA findings, should be presented.

As rules and regulations among states continue to develop, field investigation methods are improved and environmental and health impacts are understood, the State of Vermont should continue to evaluate HVHF and the overall environmental and public health impacts of unconventional oil and gas production.

F. Acronyms and Terms

ANR-DEC – Agency of Natural Resources – Department of Environmental Conservation

API – American Petroleum Institute

CAA – Clean Air Act

CERCLA – Comprehensive Environmental Response and Recovery Act

CH4- Methane

Club – Sierra Club

CO2 – Carbon Dioxide

CWA – Clean Water Act

DBP – Disinfection Byproduct

dSGEIS – State of New York, Draft Supplemental Generic Environmental Impact Statement

EIA – Energy Information Agency

GHG – Green House Gas

GWP – Global Warming Potential

HF – Hydraulic Fracturing

HVHF – High Volume Hydraulic Fracturing

IOGCC - Interstate Oil and Gas Compact Commission

MCL – Maximum Contaminant Level

MOA - Memorandum of Agreement

MOU-Memorandum of Understanding

NEPA - The National Environmental Policy Act

NGORB – Natural Gas and Oil Resource Board

N2O- Nitrous Oxide

NOM- Naturally Occurring Organic Materials

NORMS – Naturally Occurring Radioactive Materials

NRB – Natural Resources Board

NSPS - New Source Protection Standards

RCRA – Resource Conservation Recovery Act

SAB – Science Advisory Board

SDWA – Safe Drinking Water Act

TDS – Total Dissolved Solids

THMs- Trihalomethanes

TSS-Total Suspended Solids

UIC – Underground Injection Control

USDW – Underground Source of Drinking Water

VOCs – Volatile Organic Compounds

G. Bibliography

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[(3)]Groundwater Protection Council. (2014). *State Oil and Gas Regulations Designed to Protect Water Resources.* Groundwater Protection Council.

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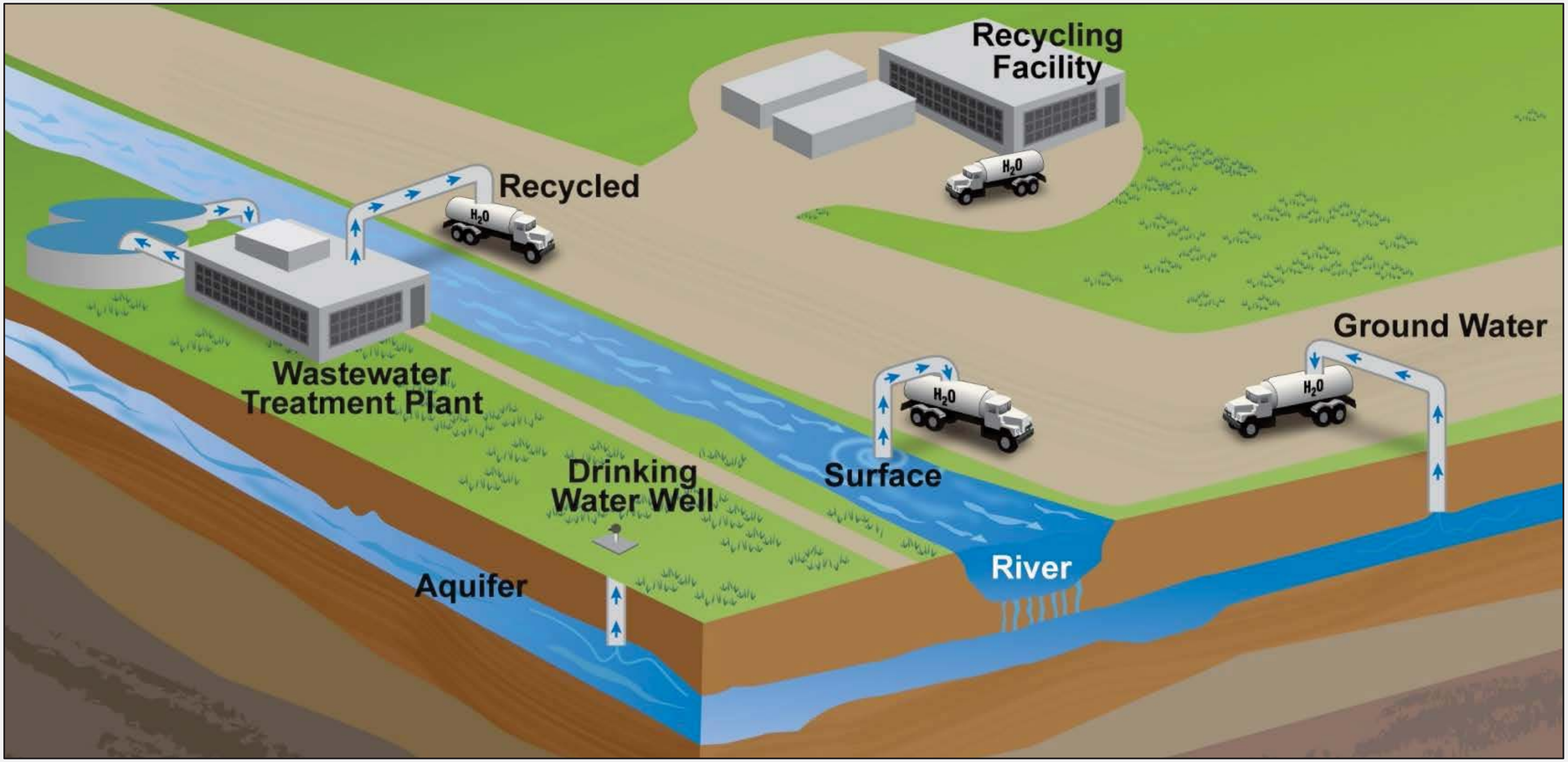
APPENDIX A

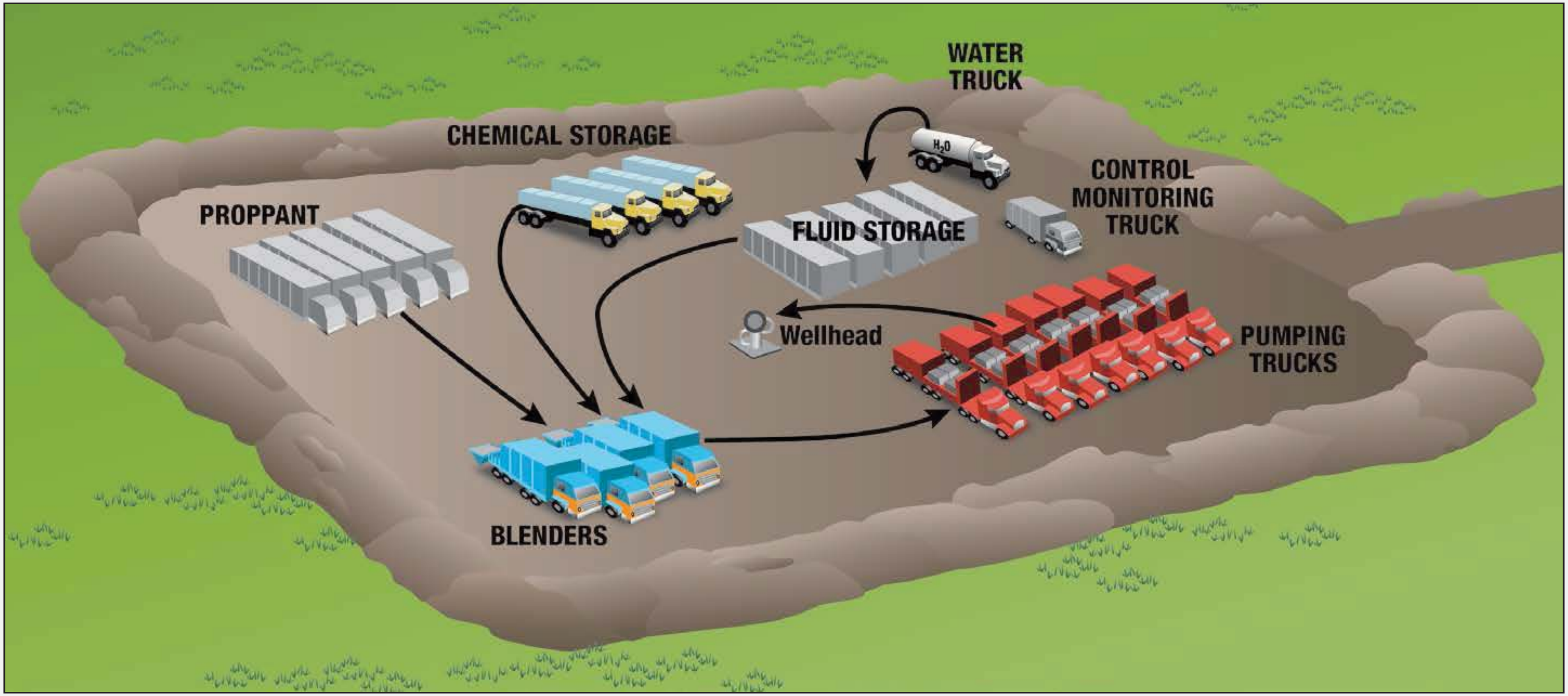
RENDERINGS OF HYDRAULIC FRACTURING ACTIVITIES

Water Acquisition



What are the possible impacts of large volume water withdrawals from ground and surface water on drinking water resources?

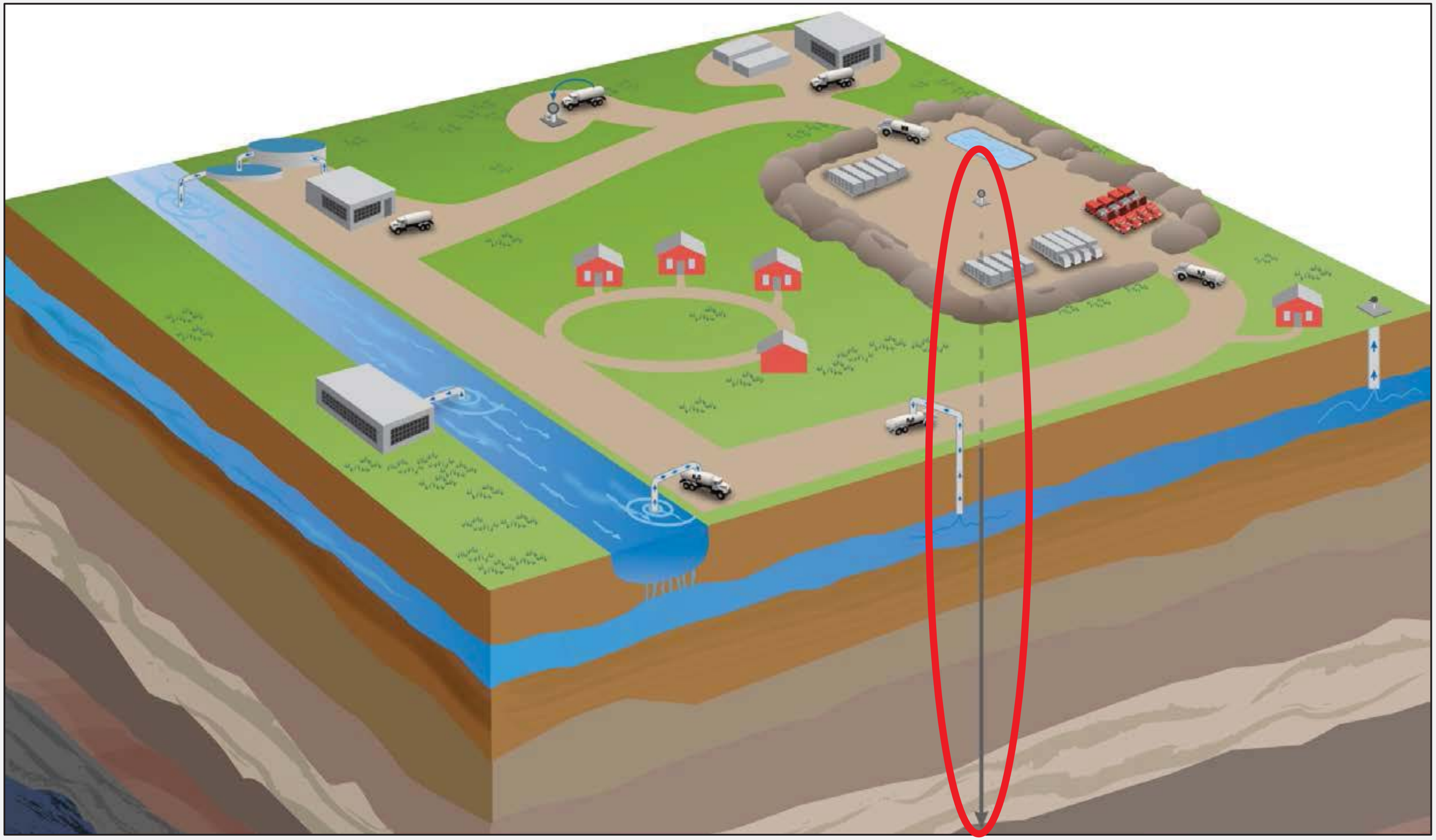
Chemical Mixing



What are the possible impacts of surface spills on or near well pads of hydraulic fracturing fluids on drinking water resources?

United States Environmental Protection Agency

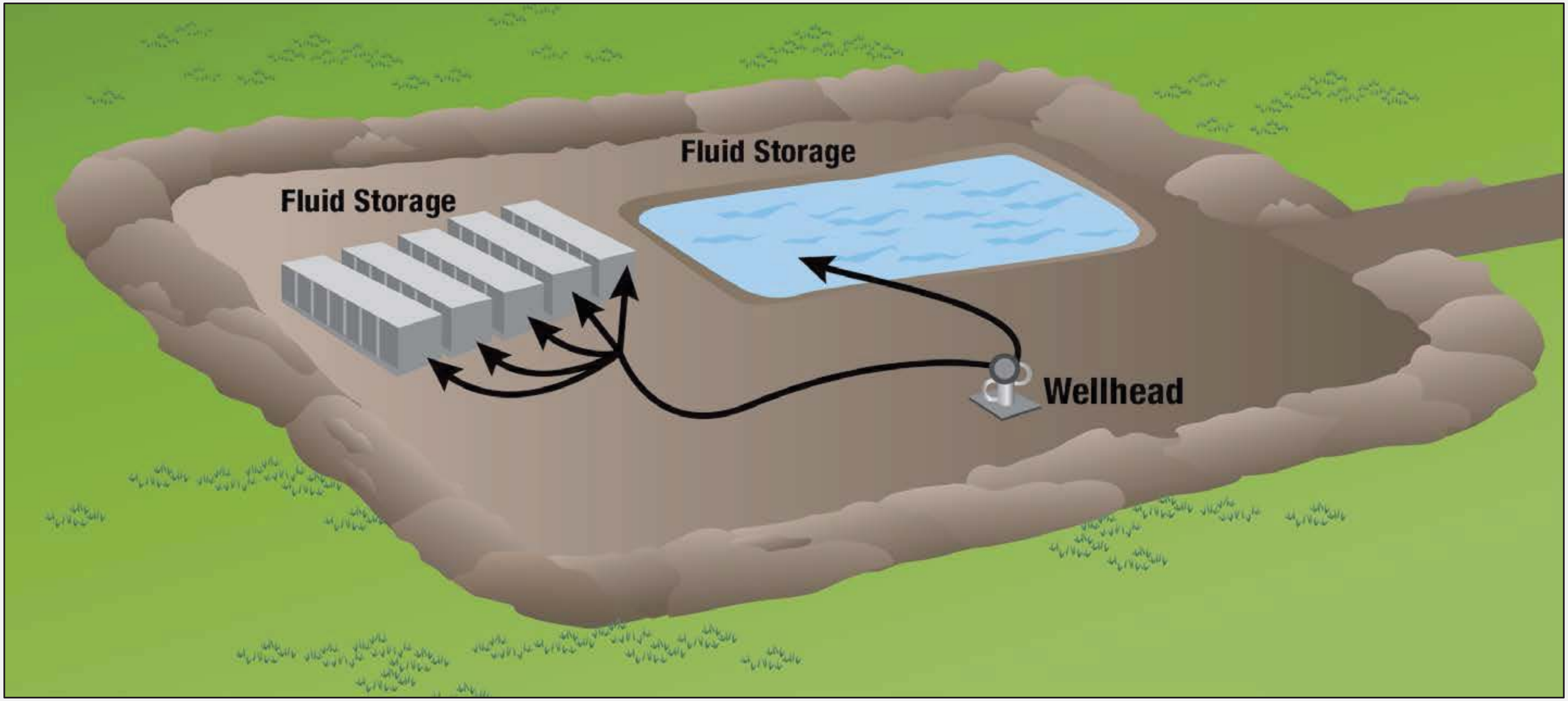
Well Injection



What are the possible impacts of the injection and fracturing process on drinking water resources?

EPA United States Environmental Protection Agency

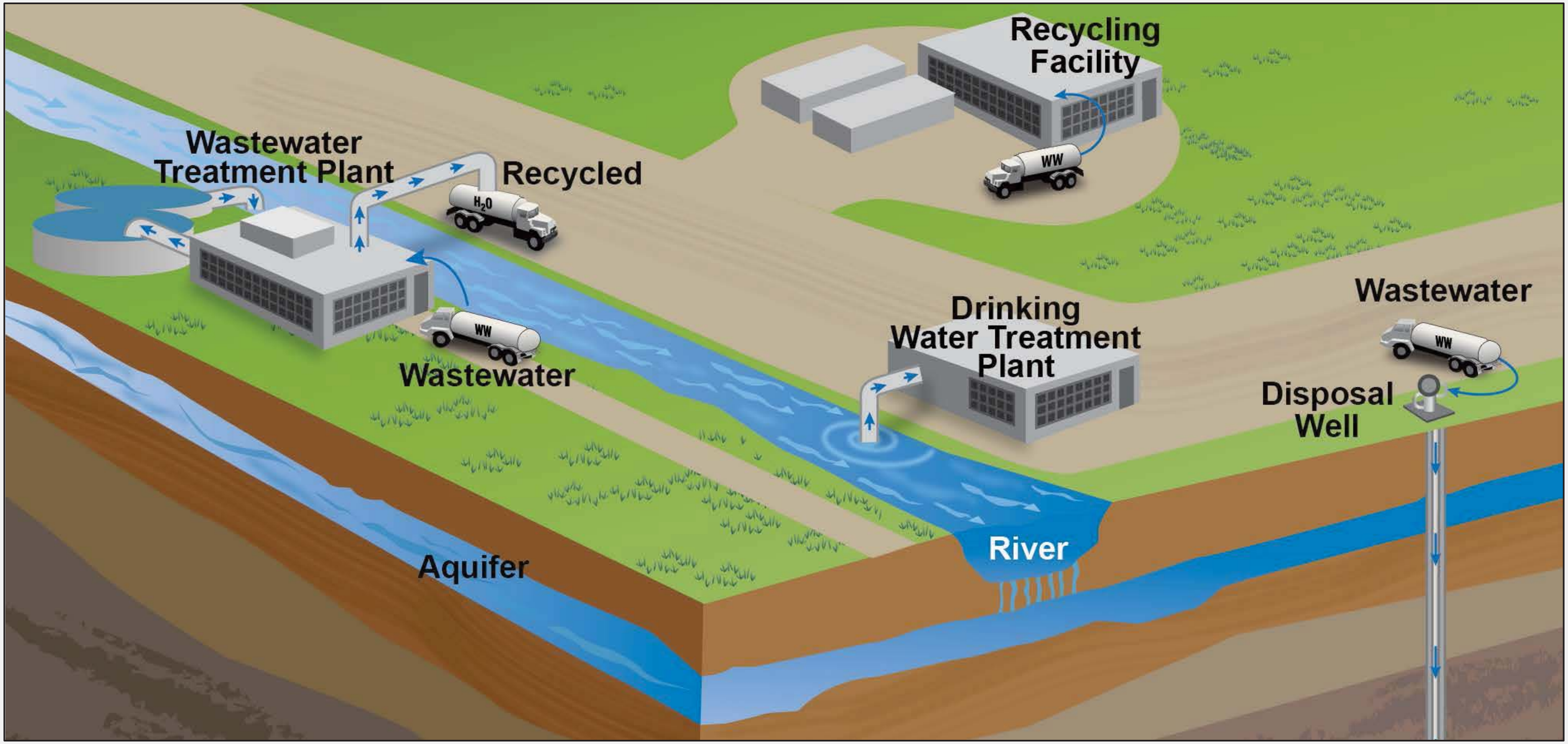
Flowback and Produced Water



What are the possible impacts of surface spills on or near well pads of flowback and produced water on drinking water resources?

EPA United States Environmental Protection Agency

Wastewater Treatment and Waste Disposal



What are the possible impacts of inadequate treatment of hydraulic fracturing wastewater on drinking water resources?

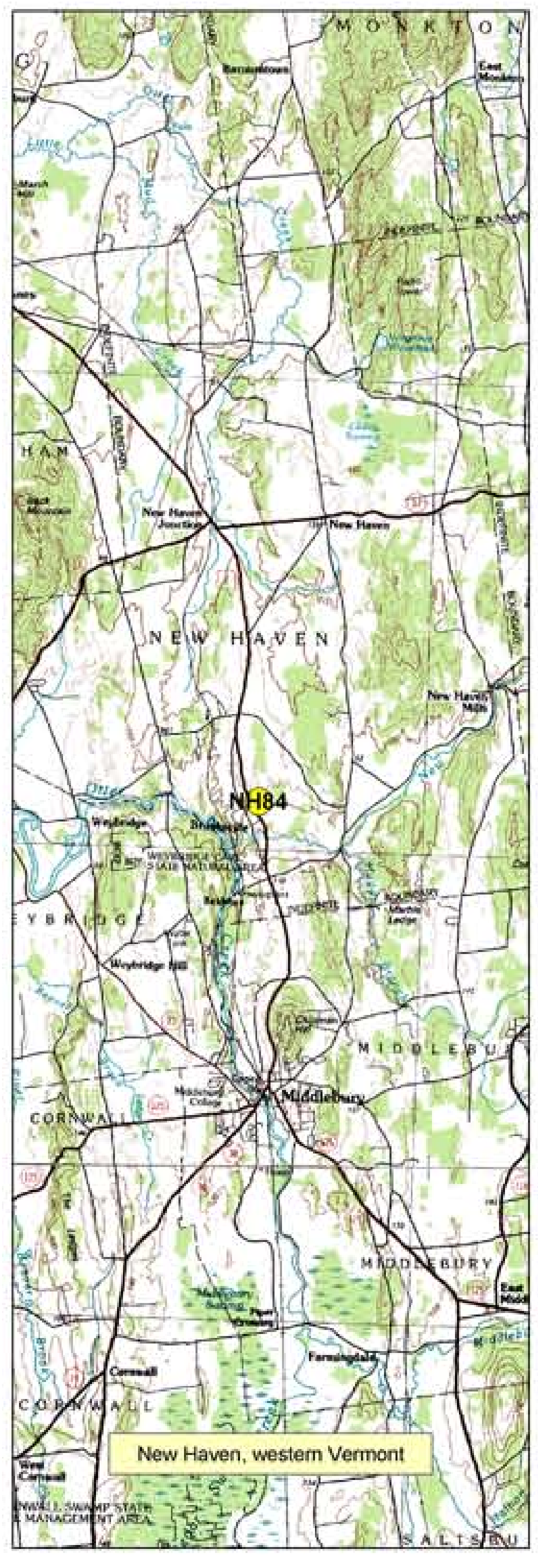
EPA United States Environmental Protection Agency

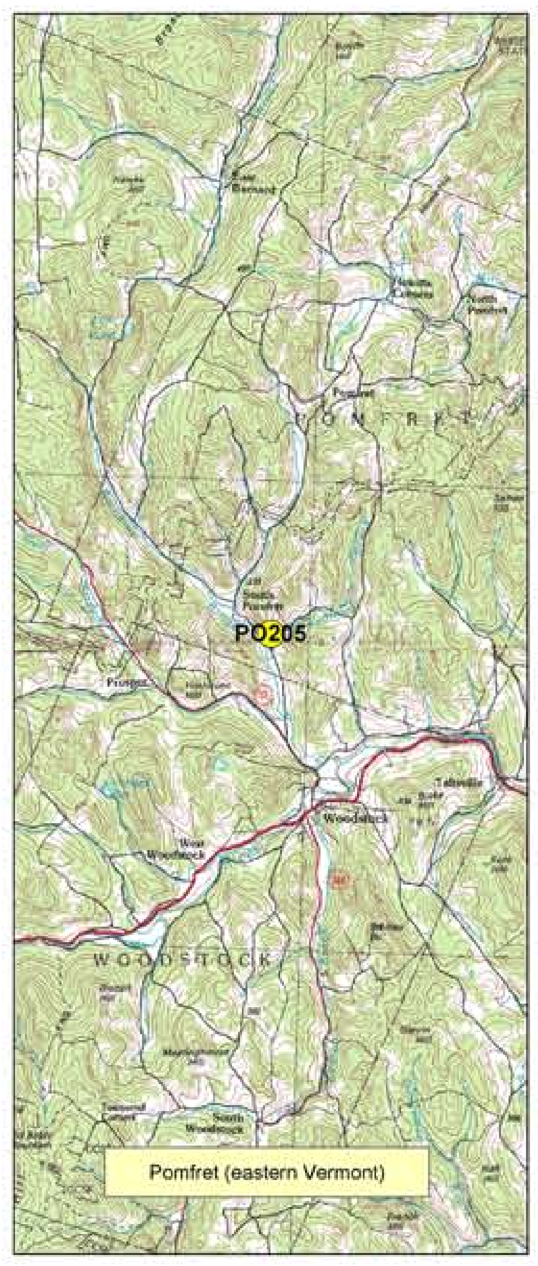
APPENDIX B

VERMONT EXPLORATORY WELL LOCATIONS

VERMONT GEOLOGICAL SURVEY

Digital cartography: Marjorie Gale





0 1 2 4 6 8 Miles

SCALE 1:100,000

Legend

- Oil/Gas Exploration Wells

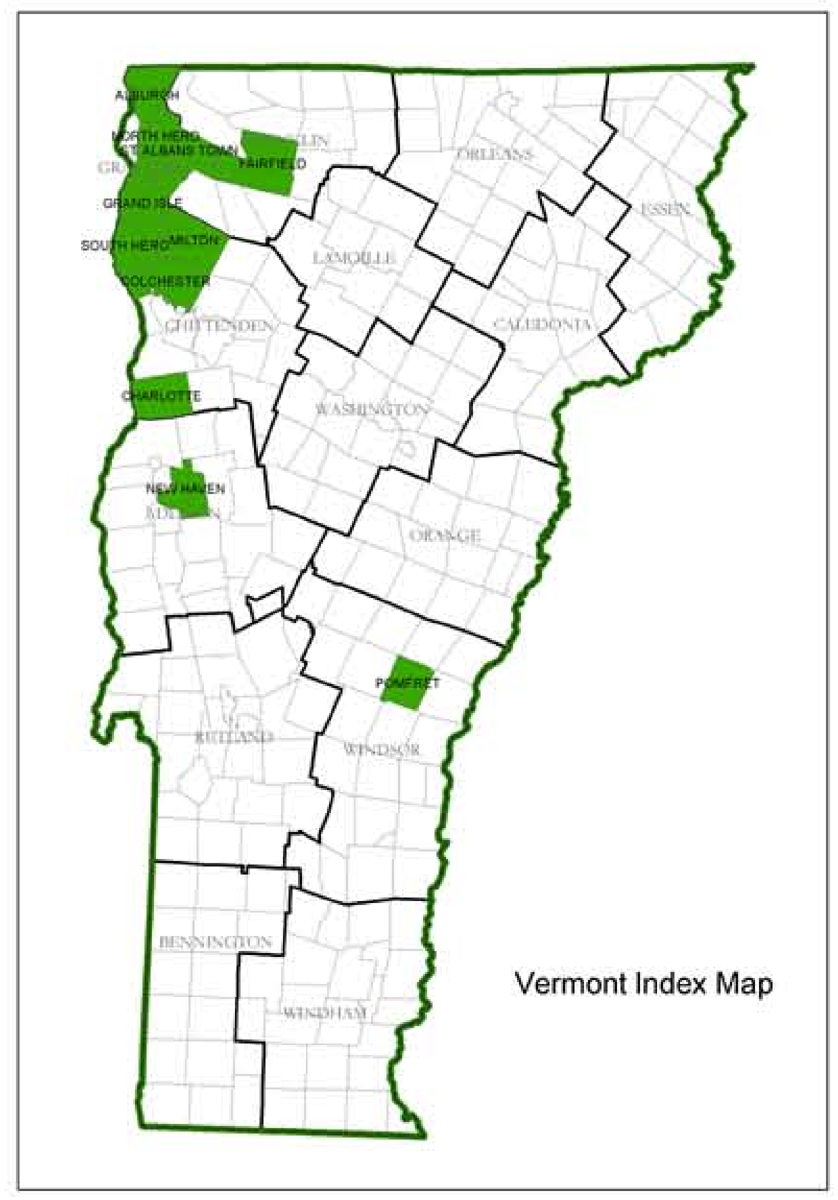
American Petrofina Wildcat - 1964
Burnor Oil & Gas Well - 1984
E.S. Baker #1 - 1968
Gregoire #1 - 1959-1960
Hazelett #1(Gregoire #2) - 1960-1961
Yandow - 1956-1957

Water wells with reported shows of gas

- Wells reported in Vermont Geological Survey files/maps
- Wells from the Water Supply Division Database Labelled by unique GIS name; Location is approximate

VT County Boundary

VT Town Boundary



Vermont Geological Survey
Dept. of Environmental Conservation, VT ANR
103 S. Main St., Logue Cottage
Waterbury, VT 05671-2420

Laurence Becker, State Geologist
802-241-3496

Vermont Oil and Gas Exploration Wells and Water Wells with Gas Shows

Vermont Geological Survey

2009

APPENDIX C

JOINT COMMENTS FROM THE AMERICAN PETROLEUM INSTITUTE TO THE

EPA SCIENCE ADVISORY BOARD

April 30, 2013

U.S. Environmental Protection Agency
EPA Docket Center
Mail Code: 28221T
1200 Constitution Avenue, NW
Washington, DC. 20460

Re: Comments of the American Petroleum Institute and America's Natural Gas Alliance on EPA's Request for Information to Inform Hydraulic Fracturing Research Related to Drinking Water Resources (77 Federal Register 67361) – Docket ID No. EPA-HQ-ORD-2010-0674

Dear Docket Clerk:

The American Petroleum Institute (API) is a national trade association representing over 500 member companies involved in all aspects of the oil and natural gas industry in the United States. America's Natural Gas Alliance (ANGA) represents 26 of North America's largest independent natural gas exploration and production companies promoting the economic, environmental and national security benefits of greater use of clean, abundant, domestic natural gas. Members of both organizations have extensive experience with the drilling and completion techniques used in developing America's oil and natural gas resources, including formations requiring hydraulic fracturing, in a safe and environmentally responsible manner.

As representatives of affected stakeholders, API and ANGA have been actively engaged in formally commenting and providing input to the U.S. Environmental Protection Agency (EPA) relative to the Congressionally-requested study to review the potential impacts of hydraulic fracturing on drinking water resources. We initially engaged Battelle Memorial Institute (Battelle) with the intent of conducting a collaborative, side by side study with EPA on its *Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources.* EPA, however, declined to engage in such a collaborative effort. In response, in early 2012, we revised our approach and commissioned Battelle to prepare a critical review of EPA's study plan and accompanying publically available supporting documents.   The critical review phase of our effort was completed in late June of 2012 and submitted to EPA on July 11, 2012.

An additional phase of work undertaken by Battelle, which we viewed as critical to a successful sound scientific assessment of hydraulic fracturing, was developed in direct response to EPA's study plan and its series of retrospective case studies.   EPA selected five locations as case study sites to determine if there is any connection between claims of contamination and nearby unconventional oil and gas development.[1] API and ANGA asked Battelle to evaluate water resource quality characteristics and variability within the retrospective study areas using readily available public data for comparison with the data to be generated by EPA. The primary objective of the work performed by Battelle was to characterize background groundwater, spring and surface water quality within each study area, and highlight known impairments and previous land use activities prior to the onset of unconventional oil and gas development. Battelle accomplished this by:

- Defining the spatial and temporal boundaries and attributes of each study area.
- Identifying land use and water quality data that could be used to provide historical context for characterizing water resources, along with identifying associated analytical parameters that could be used to evaluate potential impacts on drinking water resources.
- Developing a list of available historical water quality parameters monitored in the study area and comparing them to EPA's retrospective study parameter list.
- Developing and applying quality assurance (QA) criteria to assess the quality of the historical water quality data.
- Conducting summary statistical analyses on the historical water quality data, including a comparison with certain state and federal water quality screening criteria for context.

Battelle used EPA's publically-available data quality objective (DQO) process to help ensure that the type and quality of pre-existing data that was collected and analyzed met the primary objective of their work (e.g. characterizing background groundwater, etc.) (EPA, 2006). The end result of Battelle's work is four separate site characterization reports:

- *Bradford-Susquehanna County, Pennsylvania Retrospective Case Study Site Characterization Report;*
- *Dunn County, North Dakota Retrospective Case Study Site Characterization Report;*
- *Washington County, Pennsylvania Retrospective Case Study Site Characterization Report; and*
- *Wise and Denton County Retrospective Case Study Site Characterization Report.*

The report titled *Summary of Characterization Reports for Retrospective Case Study Areas* summarizes key elements of these four retrospective site reports and discusses why the Raton Basin, Colorado retrospective site was not included as part of Battelle's full background evaluation.

API and ANGA are now submitting this cover letter and the full reports for EPA's further evaluation and consideration as part of its November 9, 2012 *Request for Information to Inform Hydraulic Fracturing Research Related to Drinking Water Resources* (77 Federal Register 67361) and for consideration by the newly selected SAB Hydraulic Fracturing Research Advisory Panel at its May 7-8, 2013 public meeting (announced in the April 5, 2013 Federal Register).

API and ANGA appreciate the opportunity to provide these important materials to EPA as part of the request for information. We will continue to work with EPA as constructive partners in this process and we look forward to the opportunity to meet and discuss the characterization reports with you in greater detail. We appreciate your recognition that openness, transparency, and stakeholder involvement are all integral parts to a successful hydraulic fracturing study.

[1] A well blowout occurred during the hydraulic fracturing stage of well development in Dunn County, North Dakota and this location was selected by EPA as a retrospective site at the request of the State of North Dakota.

Sincerely,

Erik Milito
Group Director
Upstream and Industry Affairs
American Petroleum Institute

Amy Farrell
Vice President, Regulatory Affairs
America's Natural Gas Alliance

Attachments

cc: Jeanne Briskin, Office of Research and Development, U.S. Environmental Protection Agency
Edward Hanlon, Designated Federal Officer, Science Advisory Board
Dr. Glenn Paulson, Science Advisor, Office of the Administrator, U.S. Environmental Protection Agency
Robert M. Sussman, Senior Policy Counsel, U.S. Environmental Protection Agency
E. Ramona Travato, Associate Assistant Administrator, Office of Research and Development, U.S. Environmental Protection Agency

(All documents are available on both the API and ANGA websites – see www.api.org or http://www.anga.us/; search "Battelle").

From: Stephanie Meadows
Sent: Tuesday, April 30, 2013 3:46 PM
To: Hanlon, Edward
Subject: API, ANGA, AXPC, IPAA joint comments on EPA's Request for Information to Inform Hydraulic Fracturing Research Related to Drinking Water Resources (77 Federal Register 67361) – Docket ID No. EPA-HQ-ORD-2010-0674.

Dear Mr. Hanlon:

Please find attached the comments of the American Petroleum Institute, America's Natural Gas Alliance, American Exploration and Production Council, and the Independent Petroleum Association of America on EPA's Request for Information to Inform Hydraulic Fracturing Research Related to Drinking Water Resources (77 Federal Register 67361) – Docket ID No. EPA-HQ-ORD-2010-0674. This submission contains one large PDF file and we would like it to be considered by the Hydraulic Fracturing Research Advisory Panel in advance of its May 7-8, 2013 public meeting.

Should you have any questions or problems receiving the document, please contact me directly.

Regards,

Stephanie Meadows

Stephanie R. Meadows
Senior Policy Advisor
Upstream
American Petroleum Institute
1220 L Street, NW
Washington, DC 20005
[redacted]

April 30, 2013

U.S. Environmental Protection Agency
EPA Docket Center
Mail Code: 28221T
1200 Constitution Avenue, NW
Washington, DC. 20460

Re: Comments of the American Petroleum Institute, America's Natural Gas Alliance, American Exploration and Production Council, and the Independent Petroleum Association of America on EPA's Request for Information to Inform Hydraulic Fracturing Research Related to Drinking Water Resources (77 Federal Register 67361) – Docket ID No. EPA-HQ-ORD-2010-0674

Dear Docket Clerk:

From the outset, the oil and gas industry, represented by its Washington, DC trade associations -- the American Petroleum Institute (API), America's Natural Gas Alliance (ANGA), American Exploration and Production Council (AXPC), and the Independent Petroleum Association of America (IPAA) -- has sought to actively engage in the Environmental Protection Agency's (EPA) research investigating the potential relationship between hydraulic fracturing and drinking water resources. The industry has provided constructive comments and input at every possible opportunity and has on numerous occasions offered the direct counsel of our scientific and technical experts. Our member organizations support the Congressional request and the corresponding mandate to use "a transparent, peer reviewed process" in order to "ensure the validity and accuracy of the data" and produce credible findings based on sound scientific analysis.

The technical comments provided in this letter further demonstrate industry's unfaltering commitment to provide a technical perspective vital to ensuring the scientific merit of EPA's research. We hope the agency considers the attached responses to the charge questions EPA submitted to its *ad hoc* SAB Panel[1] and our comments on the EPA 2012 Progress Report.

In general, the technical comments provide are related to the following aspect of EPA's study:

[1] Identified on the SAB's website:
http://yosemite.epa.gov/sab/sabproduct.nsf/02ad90b136fc21ef85256eba00436459/B436304BA804E3F885257A5B00521B3B/$File/Charge+Questions-HF+Panel-May+2013+meeting-Final.pdf

- ***Purpose:*** EPA has not appropriately acknowledged the limitations of its research to achieve the agency's stated goal of informing the public and providing decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes.
- ***Scope:*** EPA appears to have deviated from Congress' request and the agency's stated scope of examining the relationship between hydraulic fracturing and drinking water resources.
- ***Systematic Planning:*** There is evidence that EPA's research would have benefited from a more robust and inclusive systematic planning process.
- ***Quality:*** There is a lack of alignment, in terms of content and timing of approvals, associated with EPA's quality documents (e.g., QAPP, QMP) and research implementation.
- ***Context:*** Critical context has been excluded from the study design, which significantly influences the value of any associated research results for the purpose of informing the public and decision makers. EPA's study approach should acknowledge state, local, and oil and gas industry requirements, plans, procedures and/or actions to prevent and respond to unfavorable conditions.

ANGA, API, AXPC, and IPAA appreciate the opportunity to provide these important comments and materials to EPA as part of the request for information. We will continue to work with EPA as constructive partners in this process and provide input on this critically important highly influential scientific assessment. We appreciate your recognition that openness, transparency, and stakeholder involvement are all integral parts to a successful hydraulic fracturing study.

Sincerely,

Amy Farrell
Vice President, Regulatory Affairs
America's Natural Gas Alliance

Erik Milito
Group Director
Upstream and Industry Affairs
American Petroleum Institute

V. Bruce Thompson
President
American Exploration & Production Council

Lee O. Fuller
Vice President of Government Relations
Independent Petroleum Association of America

cc: Jeanne Briskin, Office of Research and Development, U.S. Environmental Protection Agency
Edward Hanlon, Designated Federal Officer, Science Advisory Board
Dr. Glenn Paulson, Science Advisor, Office of the Administrator, U.S. Environmental Protection Agency
Robert M. Sussman, Senior Policy Counsel, U.S. Environmental Protection Agency
E. Ramona Travato, Associate Assistant Administrator, Office of Research and Development, U.S. Environmental Protection Agency

Responses to SAB Panel Charge Questions

Water Acquisition

1. *Water Quality.* What spatial and temporal scales should be considered for this analysis to best characterize the impacts, if any, on the quality of water used as a source of drinking water?

   Water use should be investigated holistically considering all water users; similar to state water planning processes. The oil and gas sector is a relatively small water user when compared to total water use. It is unclear how water quantity and quality impacts will be attributed to oil and gas operations, specifically hydraulic fracturing, within EPA's research given the connectivity between all water users and water resources. Water quality impacts associated with water acquisition that are not unique to hydraulic fracturing should not be attributed to the process, regardless of the spatial or temporal scales selected by EPA.

   - *Texas 2008: 0.003% (57 k acre-feet) and 0.002% (35.8 k acre-feet) of the total water use was O&G and hydraulic fracturing, respectively.*[2]
   - *Texas 2010: Mining, which includes but is not limited to the oil and gas sector, made up 1.8% of the total state water use.*[3]
   - *Colorado 2010: 0.08% (13.9 k acre-feet) of the total state water use was hydraulic fracturing.*[4]
   - *Oklahoma 2012: Oil and gas drilling and hydraulic fracturing accounts for a very small fraction (less than 1%) of freshwater use in Oklahoma.*[5]

   It is concerning that EPA has not referenced or considered incorporating state water planning processes or reports within the agency's research. When considering water use as an energy investment, unconventional oil and gas has one of the highest rates of return[6] *relative to other energy sources.*

   Regional, state, and local water regulators and water ownership legal doctrines appropriately allocate all water rights. Regulators' water management efforts include responding to short-term and long-term local environmental conditions. This context should be incorporated into the study design to avoid unrealistic and biased results; specifically, the scenario models must consider the existing regulatory structure (e.g., private property right issues associated with water rights), as well as operational boundaries.

   In direct response to EPA's charge questions, the agency should include a diverse range of spatial and temporal scales within the agency's research to ensure an appropriate level of context is provided to the public. Without the appropriate context

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[2] http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-RRC.pdf
[3] http://www.twdb.state.tx.us/waterplanning/waterusesurvey/estimates/
[4] http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf
[5] http://oklahomawatersurvey.org/d1/wp-content/uploads/2012/10/04-OGS.pdf
[6] http://www.epa.gov/hfstudy/09_Mantell_-_Reuse_508.pdf

surrounding water quality impacts associated with water acquisition in general, and those specific to hydraulic fracturing, research results will not contribute to EPA's goal to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes.

2. *Water Quality.* Please identify the most important water quality characteristics that should be considered.

   It is unclear how water quantity and quality impacts will be attributed to oil and gas operations, or specifically hydraulic fracturing, within EPA's research given the connectivity between all water users and water resources. Since water acquisition is not unique to hydraulic fracturing, water quality impacts associated with water acquisition would not be unique to hydraulic fracturing. Therefore, no water quality characteristic can be considered specifically or arbitrarily attributed to water acquisition associated with hydraulic fracturing.

3. *Water Availability.* What spatial and temporal scales should be considered for this analysis to best characterize the impacts, if any, on the availability of water used as a source of drinking water?

   Water use should be investigated holistically considering all water users; similar to state water planning processes. The oil and gas sector is a relatively small water user when compared to total water use. It is unclear how water quantity and quality impacts will be attributed to oil and gas operations, specifically hydraulic fracturing, within EPA's research given the connectivity between all water users and water resources. Water quality impacts associated with water acquisition that are not unique to hydraulic fracturing should not be attributed to the process, regardless of the spatial or temporal scales selected by EPA.

   It is concerning that EPA has not referenced or considered incorporating state water planning processes or reports within agency's research. Regional, state, and local water regulators and water ownership legal doctrines appropriately allocate all water rights and, as part of their water management efforts, respond to short-term and long-term local environmental conditions. This context should be incorporated into the study design to avoid unrealistic results; specifically, the scenario models must consider the existing regulatory structure (e.g., private property right issues associated with water rights), as well as operational boundaries.

   Given the insignificant use of fresh water in the Upper Colorado River Basin (UCRB) for the hydraulic fracturing process (i.e., 100% reused water), it appears EPA has stepped outside the scope ("hydraulic fracturing water life-cycle") of the study to investigate land use (i.e., pad constructions). It is recommended that EPA not expand the scope of the UCRB research beyond the hydraulic fracturing process.

   There appear to be significant flaws in EPA's identified future modeling scenarios and associated assumptions. For example, the model does not appear to take into consideration local regulatory authority to prioritize water use during drought conditions and operational practices to acquire/store water during wet seasons. The modeling also does not appear to account for opportunities for use of water under other existing water use permits. The inclusion of two additional scenarios in the analysis would be of value;

“no hydraulic fracturing activity” and “low hydraulic fracturing activity” scenarios. These scenarios would provide the appropriate context necessary to understand the relative influence of hydraulic fracturing on water availability for a given area.

We also encourage the agency to avoid the use of the term "green technologies" as there is no pre-defined set of technologies or practices that can be considered “green” in all operating situations. For example, in some cases simple fresh water acquisition and Class II UIC disposal of produced water could be the “greenest” alternative from a holistic environmental/multi-media perspective.

In direct response to EPA’s charge questions, the agency should include a diverse range of spatial and temporal scales within the agency’s research to ensure an appropriate level context is provided to the public. Without the appropriate context surrounding water availability impacts associated with water acquisition in general and those specific to hydraulic fracturing research results will not contribute to EPA’s goal to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes.

Chemical Mixing

1. Given the data sets available, what information on fluid composition, factors affecting composition, and/or trends in composition of hydraulic fracturing fluids may be most useful for identifying potential impacts to drinking water resources across the United States?

Fluid composition, factors affecting composition, and/or trends in composition should not be EPA’s primary focus as it investigates the potential relationship between drinking water resources and hydraulic fracturing. EPA’s study approach should acknowledge state, local, and oil and gas industry requirements, plans, procedures and/or actions to prevent, respond and control leaks and/or releases. In the rare occurrence of an unintentional environmental release, industry members act appropriately in conjunction with local authorities and in accordance with regulatory requirements to limit the impact on the environment and ensure the health and safety of the public. Not considering these facts will undoubtedly result in conclusions that are misrepresentative.

The ultimate goal of hydraulic fracturing is to stimulate the unconventional reservoir in order to recover hydrocarbons in the safest and most efficient manner possible. The composition of fracturing fluids and associated chemical additives used are fit for purpose, optimized to deliver the desired production performance and, therefore, designed to obtain the greatest return on the natural resources (e.g., water used, surface disturbance, etc.) and financial investment made throughout the well development process. This includes the use of chemicals for well integrity assurance. Significant technological advancements have recently been made in increasing the efficiency of fracturing-execution, including methods to decrease the total volume of injected fluid, chemical additives, and propping agents. There is no simple formula or process that constitutes the most effective and environmentally friendly approach to well stimulation. For example, more benign chemicals, in some cases, can reduce the *efficiency of stimulation and result in additional wells, re-stimulation, additional cost, and/or lower ultimate recovery from the well. Thus, what might through a simplistic lens appear to be environmentally beneficial could actually increase the overall environmental footprint associated with development.*

Hydraulic fracturing fluid composition varies among plays. Water is by far the most common base fluid, however, other media (e.g., nitrogen, propane, CO_2, etc.) have been utilized and continue to be evaluated for application on a case-by-case basis. After the base fluid, proppant is typically the second largest component of which sand is the common material used. Additives make up a small fraction (typically <1%) of the total frac fluid volume, and they are added only as required to achieve stimulation and well integrity performance objectives. Changes in additive make-up generally occur throughout the discovery and development of a play due to continuous refinement and improvement for treatment performance and, ultimately, hydrocarbon recovery.

The development and application of hydraulic fracturing additives that can perform effectively when produced water or alternative water sources are used in stimulation fluids can reduce alternate dependency on fresh water use. Operators and service companies continue to develop and apply more benign chemical additives and fracturing fluid mixtures on a case-by-case basis. Intellectual property right protection can have a significant impact on corporate incentives to develop technologies in these areas.

The general composition of hydraulic fracturing additives is known and many hydraulic fracturing chemical additives are found in common household products.[7] MSDS' contain information that is necessary to understand the potential health and safety hazards. The study focus should be placed on the known major constituents, not investigation of trace elements and impurities. There are also opportunities to improve the analytical methods used for laboratory testing of additives.

2. What key historical changes or current trends, if any, in hydraulic fracturing fluid composition should be considered as the EPA assesses the chemicals listed in Appendix A?

   The agency should not inappropriately generalize results; it is strongly recommended that EPA evaluate all data within an appropriate temporal and spatial context. All historical data collected - including that obtained during EPA's RFI processes - should be analyzed in the appropriate context, accounting for continuous industry practice[8] and more protective state regulatory programs that evolve as both parties use their operational experience to innovate and strive for the common goal of maximizing production while ensuring protection of the environment and health and safety of personnel and the public.

3. What criteria should be considered when identifying indicator chemicals, and why?

[7] http://www.same-satx.org/briefs/120410-holditch.pdf
[8] http://www.askchesapeake.com/Pages/Green-Frac.aspx

The use of key indicator compounds (TDS, Cl, and divalent cations) is the most reliable, efficient, and cost effective method for the initial investigation of suspected or known produced water releases. The concept of utilizing indicator compounds in the environmental field is well established[9] (e.g., Ohio[10], Louisiana[11], Oklahoma[12], Arkansas[13], California[14], Texas[15], etc.).

Sampling and analyzing for key indicator compounds using current proven analytical methods in multiple matrices offers a superior alternative to the development of new methods for constituents that will change as hydraulic fracturing fluids evolve. In the unlikely event of a produced water release, TDS, TPH, chloride, sodium, bromide, sulfate, etc. are well suited indicators. These compounds have been historically evaluated in many, if not most, groundwater aquifers used for domestic purposes, providing good background data for comparative purposes. The identification and use of key indicator compounds representative of a known hydraulic fracture fluid composition that can be detected using existing approved methods can eliminate the need for the development and use of new analytical methods. Analytical methods, which evaluate groups of compounds, e.g. TOC, TPH, TKN, etc., may be useful in getting sufficient information to assess the impact of fluid releases in an emergency situation.

Toxicity should not be a selection criterion for indicator compounds when the primary goal is to determine the relationship, if any, between hydraulic fracturing and drinking water. Caution should be taken when attempting to use glycols as an indicator because they are ubiquitous in the environment and are found in laboratory preservatives, water well construction material, and automotive anti-freeze. Iron and manganese are also poor indicators to use since they are highly influenced by sediment in the water samples. The following criteria should be considered when identifying key indicator compounds:

- *Frequency of occurrence in hydraulic fracturing fluids and produced water*
- *Uniqueness to hydraulic fracturing and produced water*
- *Stability and mobility in the environmental (fate and transport)*
- *Availability of instrumentation/detection systems, limits, and approved analytical methods for the parameter.*

Well Injection

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[9] National Environmental Monitoring Conference, Topics in Shale Gas Exploration Session, August 7, 2012 http://nemc.us/meeting/2012/nemc-program.php#apm7_6 (Coleman, McElreath, Mantell)
[10] http://www.epa.state.oh.us/portals/30/rules/DI-033.pdf
[11] http://www.deq.louisiana.gov/portal/Portals/0/RemediationServices/APPENDIXD.pdf
[12] http://www.occeweb.com/rules/Chapter%2029%20Effective%207-1-09%20SOS.pdf
[13] http://www.adeq.state.ar.us/hazwaste/branch_tech/pdfs/tph_sls_web_version.pdf
[14] http://www.dtsc.ca.gov/AssessingRisk/upload/HHRA-Note-4.pdf
[15] http://www.tceq.texas.gov/publications/rg/rg-366_trrp_27.html

1. Given that hydraulic fracturing occurs at different depths and in different types of rock formations, please comment on how to best use results from these simulations to answer the research questions listed in Table 26 (page 62).

   Modeling the subsurface is inherently an extremely complex problem. Using a simplified modeling approach can lead to incorrect conclusions, particularly if limitations of the modeling approach are not fully acknowledged and understood and the results are not presented in the appropriate context.

   The scenarios, assumptions, and verification do not appear to be presented in enough detail within the study plan, progress report or LBNL Modeling QAPP to guide this highly influential research or inform peer reviewers. All presented scenarios are based on multiple barriers failing. The most valuable scenarios – no hydraulic fracturing and no failures - are missing from this research. Based on publically available information regarding this research effort, the usefulness of the current modeling effort is limited.

   It is concerning that this charge question appears to be indicative of a lack of systematic planning by EPA. The modeling research should have been designed specifically to answer appropriate research charge questions.

2. Please comment on other ways the information listed above may be used to characterize the effectiveness of well construction and operation practices at protecting drinking water resources.

   Wells are designed with multiple barriers (steel, cement, seals, etc.) intended to isolate ground water resources from the target hydrocarbon reservoirs and fluids flowing in the well. EPA should consider all layers of protection that are currently required or widely practiced, as well as monitoring and response capabilities. Each layer of protection should be assessed independently, rather than EPA's current methodology that assumes multiple layers fail without consideration of monitoring and response. A well barrier can fail internally but will not result in a release to the environment when outer barriers confine the failure. This context should be included when presenting well failure information to the public and other stakeholders.

   EPA's study approach does not appear to acknowledge state, local, and oil and gas industry plans, procedures and/or actions to respond to abnormal conditions (e.g., indication of potential or actual barrier failure). In the rare occurrence of an abnormal condition, industry members act appropriately in conjunction with local authorities and in accordance with regulatory requirements to limit the impact on the environment and ensure the health and safety of the public. Not considering this fact will undoubtedly result in conclusions that are misrepresentative.

   EPA should assess all information about barriers and risk management practices holistically. A well-established risk assessment and risk characterization framework is appropriate for this (and other) research topics.

Flowback and Produced Water

1. Please identify specific data or literature on the composition of flowback and produced water in other areas of the country.

   Produced water characteristics vary significantly temporally within, and spatially between, basins, formation, and wells. EPA does not appear to have captured the breadth of these variations within the agency's current plan. The characteristics of produced water have been studied significantly by USGS[16]. Analytical techniques used to characterize produced water must be robust to the matrix interferences resulting from high TDS concentrations.[17] Industry has and continues to participate in a number of collaborative groups regarding the characterization of produced water - Brine Chemistry Consortium[18] (20 + years) and Shale Water Research Center[19] (1 year).

   EPA has made a distinction between produced water and flowback. Produced water consists of all water that is returned to the surface through a well borehole. "Flowback" process water should be considered a subset of produced water returned during the flowback process. The only factor that is used in defining this subset of produced water is the time period in which the water is returned to the surface through the well borehole. It is not necessary or appropriate to use the term "flowback" to differentiate produced water quality.

2. Please suggest ways for the EPA to use these or other data to more comprehensively assess how spills or leaks may impact drinking water resources.

   "Reported" or "potential" spills that have not been confirmed/validated should not be considered reliable data for a risk (likelihood and severity) analysis. For example, tip or complaint lines should not be considered appropriate data resources. In addition, many spills that are still reported may have been isolated through containment devices lined with impermeable materials (i.e., synthetic liner, coated concrete, steel, or compacted clay). Spills kept within impermeable containments have little or no potential to impact underlying soils or groundwater. Caution needs to be taken when evaluating spill databases to ensure accuracy, consistency, and comparability of reported spills, including the appropriate segregation of spill types (e.g., solids or liquids) and ensuring spills that were reported by more than one entity are captured only once in the analysis. Spills related to auxiliary activities and/or processes (e.g., pipelines) should not be included in this evaluation because it is out of the scope of the study.

   EPA's study approach does not appear to acknowledge state, local, and oil and gas industry plans, procedures and/or actions to respond and control leaks and/or releases. In the rare occurrence of an unintentional environmental release, industry members act appropriately in conjunction with local authorities and in accordance with regulatory requirement to limit the impact on the environment and ensure the health and safety of

[16] http://energy.cr.usgs.gov/prov/prodwat/
[17] http://www.epa.gov/hfstudy/producedformationwatersampleresultsfromshaleplays.pdf
[18] http://www.brinechem.rice.edu/partners.cfm
[19] http://www.shalewatercenter.com/

the public. Not considering this fact will undoubtedly result in conclusions that are misrepresentative.

Like other industries, the oil and gas sector continues to develop and deploy practices that reduce associated environmental risks. These practices are typically evaluated on a case-by-case basis with careful consideration of unintentional consequences. For example, regarding spills, pad containment and various construction materials can be used to mitigate the risk of release to the environment.

It is concerning that this charge question appears to be indicative of a lack systematic planning by EPA. The research should have been designed specifically to answer appropriate research charge questions.

Wastewater Treatment and Waste Disposal

1. Please provide recommendations for other specific chemicals that are of interest from a wastewater treatment and/or drinking water treatment perspective.

   Sampling and analyzing key indicator compounds utilizing current proven analytical methods in multiple matrices offer a superior alternative to the development of new methods for constituents that will change based on local conditions and over time as hydraulic fracturing fluids evolve. Within EPA's 2012 Progress Report, the agency clearly states that chemicals found in hydraulic fracturing additives are ubiquitous and many of the parameters of interest are naturally occurring. Understanding background conditions and natural variation (including seasonality and intra-well variability) in parameters of interest is critical to determining if an impact has occurred and assessing the possible cause of the alleged impact.

2. What key trends in wastewater management, if any, may affect the volume and/or composition of hydraulic fracturing wastewater being treated and discharged to surface water?

   Industry strives for continuous improvement in the application of produced water management alternatives. These efforts are driven by stewardship, environmental/corporate risk reduction, and economics. A number of complex operational, logistical, environmental, health, safety, regulatory, and economic factors and associated risks are evaluated prior to the development, selection, and implementation of produced water management practices or strategies. The interrelationships and trade-offs among the various aspects of decision factors industry uses in determining water management practices should be carefully considered and addressed for this study. For example, reuse of produced water for hydraulic fracturing could require more chemical volume, less benign chemicals, and/or more storage and treatment facilities. The complexities and tradeoffs involved in determining the most efficient or environmentally benign approach to development require case-by-case analysis based on local conditions and should not be generalized in the study.

   Class II disposal wells, regulated under EPA's Underground Injection Control (UIC) program, are the primary method for produced water disposal and require zero surface *discharge. And, the composition of all wastewater discharge, including discharge of any wastewater from oil and gas operation to surface water, is regulated under the National Pollution Discharge Elimination System (NPDES) permit program. EPA or states issue permits that establish water quality treatment standards and volumetric limits for effluent, which are frequently monitored, analyzed, and reported to demonstrate compliance with the standards and limits established.*

Page	Section	Report Citation	Comment	References
1	ES	The purpose of the study is to assess the potential impacts of hydraulic fracturing on drinking water resources, if any, and to identify the driving factors that may affect the severity and frequency of such impacts.	Throughout the report the discussion of potential risk (likelihood and uncertainty) needs to be included. A review of hazards and factors without this context will lead to misunderstanding. Hazards, factors, and likelihood should be presented in a relative manner to the public; specifically, the EPA should provide examples and comparisons of relative risks that are familiar to the public. Sequence - more specifically the lack of sequence - of research is concerning. There appears to be activity that should be taking place in series, rather than taking place in parallel. This will reduce the value of some of the research.	
1	ES	Information presented as part of this report cannot be used to draw conclusions about potential impacts to drinking water resources from hydraulic fracturing.	This is an important disclaimer. Based on a critical review of associated study materials, this disclaimer may be necessary for all reports associated with EPA's HF research.	
2	ES	Data within these records are being scrutinized to assess the effectiveness of current well construction practices at containing gases and liquids before, during, and after hydraulic fracturing.	Overwhelming data shows that the hydraulic fracturing technique poses little risk to groundwater due to multiple geological and well design features. Industry recognizes that sound operational practices concerning well construction and integrity, water management, air emissions, and surface impacts exist and must be followed to prevent accidental releases and mitigate other concerns (Fisher 2010, 2012; King 2010, 2012; Kell, 2011; Arthur, 2009, 2012).	
2	ES	Identified hypothetical, but realistic, scenarios pertaining to the water acquisition, well injection, and wastewater treatment and waste disposal stages of the water cycle.	States have established regulations to manage sourcing/acquisition, produced water disposal, and treatment (e.g., permitting, construction, operation, etc.) and are continually updating these requirements as appropriate for local conditions. This context should be incorporated into the study design. Consultation with regional, state, and local regulators, as well as industry, in the areas of this research is critical to ensure scenarios are realistic and consistent with their historical laws and policies.	
3	ES	As a first step, the subsurface migration simulations will examine realistic scenarios to assess the conditions necessary for hydraulic communication rather than the probability of migration occurring.	Realistic scenario would consider regulation and practices in place to identify and respond to abnormal conditions. For example, casing pressure and annular pressure monitoring are done on every well by mechanical and human monitoring (Augustine, 2010). Automatic pressure relief valves (reliability of approximately 99.99%) are present on most jobs. Ruptured casing during a frac is extremely rare. Without consideration of requirements and practices associated with monitoring and response, scenarios would not be considered realistic.	

Page	Section	Report Citation	Comment	References
3	ES	Laboratory studies are largely focused on identifying potential impacts of inadequately treating hydraulic fracturing wastewater and discharging it to rivers.	The disposal of produced water in POTWs is very rare, if used at all, for unconventional oil and gas operations. The utilization of this option should be managed on a case-by-case basis with a firm understanding of the plants efficiency in removing appropriate compounds. Efficiency of all treatment processes are influenced by technological and operational factors. This context should be incorporated into the study design; specifically, the interpretation of laboratory experiments.	
3	ES	The EPA has identified chemicals reportedly used in hydraulic fracturing fluids from 2005 to 2011 and chemicals found in flowback and produced water.	Timeliness of the data is concerning and presentation of data is misleading to the public and policy makers.	
3	ES	This research will help to identify the source of any contamination that may have occurred.	EPA has not shared how they are going to determine the source of contamination. Paucity of background data and an insufficient study design will hamper EPA's ability to differentiate among all potential sources of contamination. Research methods for determining the source of contamination have not been documented prior to sampling, including the collection of baseline or background data including historical land use and environmental conditions.	
3	ES	Prospective study...involve sites where the research will begin before **well construction**….Water quality will be monitored for **any changes** throughout **drilling**, injection of fracturing fluids, flowback, and production.	A true baseline for hydraulic fracturing would be sampling after drilling and well construction. Data from state investigations and studies in Ohio and Texas (Kell, 2011) show very small percentages of construction well failures leading to pollution and none related directly to fracturing.	
3	ES	Samples of flowback and produced water will be used for other parts of the study, such as assessing the efficacy of wastewater treatment processes at removing contaminants in hydraulic fracturing wastewater.	There appears to be a misconception that all parameters should be removed from produced water during a treatment process. Treatment of produced waters must reflect reuse or disposal criteria.	
4	ES	Increased stakeholder engagement will also allow the EPA to educate and inform the public of the study's goals, design, and progress.	We support increased stakeholder involvement, but are concerned that sufficient engagement and collaboration did not occur at the outset of the planning phase of the study. We also note that the purpose of engagement should not be simply to "allow EPA to educate and inform the public," but that EPA should recognize and incorporate guidance from significant external technical expertise, particularly those experts in industry.	
4	ES	Research products, such as papers or reports, will be subjected to both internal and external peer review before publication, which make certain that the data are used appropriately.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each, and the projected timeline for review completion.	

Page	Section	Report Citation	Comment	References
4	ES	The EPA will seek input from individual members of an ad hoc expert panel convened under the auspices of the EPA Science Advisory Board.	EPA should provide all SAB Panel members and other stakeholders with an opportunity to provide input. EPA should not cherry pick the individual members that will be consulted on specific charge questions.	
4	ES	Ultimately, the results of this study are expected to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes.	EPA should acknowledge the limitations associated with its research and expected report of results. Specifically, the agency appears to be misrepresenting the ability of the public or decision makers to use the information currently being gathered or generated prior to conducting formal risk assessment and risk characterization. In particular EPA should be mindful of the limits the lack of sufficient background data will place on its ability to attribute water quality impairment to any particular potential source of contamination.	http://www.epa.gov/spc/pdfs/rchandbk.pdf
4	ES	Look Forward: From This Report to the Next	There is no acknowledgement of the roundtable and/or workshop technical engagements in this process. EPA should indicate whether and how that process will be used to improve its study methodology.	
6	1	Results from individual projects will undergo peer review prior to publication.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each and the projected timeline for review completion.	
7	1.1.	Information presented during the [2011] workshops is being used to inform ongoing research.	There appears to be a wealth of technical information that was presented during EPA's 2011 technical workshops that has not been used to inform the study or it has been referenced incorrectly. EPA should update its website to include an explanation of whether and how presentations from the 2011 workshops were or were not incorporated.	
7	1.1.	ensure that the EPA is current on changes in industry practices and technologies so that the report of results reflects an up-to-date picture of hydraulic fracturing operations	All historic data collected - including that obtained during EPA's RFI processes - should be analyzed in the appropriate context, accounting for continuous industry practice and updated state regulatory programs that evolve as both parties use their operational experience to innovate and strive for the common goal of maximizing production while ensuring protection of the environment and health and safety of personnel and the public.	
7	1.1.	Stakeholder Engagements… These efforts will help: …. Identify **future** research needs.	EPA should focus the agency's finite resources on the scope request by Congress, as recommended by the SAB Environmental Engineering Committee.	http://yosemite.epa.gov/sab/sabproduct.nsf/368203f97a15308a852574ba005bbd01/CC09DE2B8B4755718525774D0044F929/$File/EPA-SAB-10-009-unsigned.pdf
11	2	Table 1. Bradford County, Pennsylvania	Susquehanna County appears to have been arbitrarily removed for the study scope. EPA should include an explanation of how it has revised the study plan and why, including a description of why Susquehanna County was removed.	

Page	Section	Report Citation	Comment	References
11	2	Table 1. Prospective Study...Investigation of potential impacts of hydraulic fracturing through collection of samples from a site before, during, and after well pad construction and hydraulic fracturing	Investigating surface disturbance (i.e., pad construction) appears to be outside the scope of the study and not unique to hydraulic fracturing or oil and gas development. There is a great amount of information and research that has been conducted on this topic and it is not necessary for EPA to reinvent the wheel. It is recommended that the agency not include costly field activities that are not absolutely necessary to answer Congress' request.	
14, 15	2.1.1	The EPA is working to better characterize the amounts and sources of water currently being used for hydraulic fracturing operations, including recycled water, and how these withdrawals may impact local drinking water quality and availability. To that end, secondary research questions have been developed, as well as the research projects listed in Table 2.	Characterization of the amount and sources of water, including current and future trends, appears to be of value. Therefore, the first secondary charge question in Table 2 seems relevant. However, the 2nd and 3rd do not appear to be unique to hydraulic fracturing and cannot be evaluated without a comprehensive evaluation of all water users and a prioritization, similar to what is included in the existing state and/or regional water planning processes water utilization laws.	
15	2.1.2	Chemicals are added to the fluid to change its properties (e.g., viscosity, pH) in order to optimize the performance of the fluid.	The development and application of hydraulic fracturing additives that can perform effectively when produced water or alternative water sources are used in stimulation fluids can reduce fresh water use. Operators and service companies continue to develop and apply environmentally conscious chemical additives and fracturing fluids mixtures on a case-by-case basis. Intellectual property right protection can have a significant impact on corporate incentives to advance technologies in these areas. In addition, some chemicals serve well-integrity purposes. This context should be included in EPA's research. Certain considerations should also be given to the increasing trend in chemical identity-disclosure, through services including fracfocus.org.	
16	2.1.3	Production wells are drilled and completed in order to best and most efficiently drain the geological reservoir of its hydrocarbon resources.	The ultimate goal of hydraulic fracturing is to stimulate unconventional reservoirs in order to recover hydrocarbons in the most efficient manner possible. The composition of frac fluids and associated chemical additives used are fit for purpose, and designed to obtain the greatest return on the natural resources (e.g., water used, surface disturbance, etc.) investment made throughout the well development process. Significant technological advancements have recently been made in increasing the efficiency of fracturing-execution, including methods to decrease the total volume of injected fluid, chemical additives, and propping agents. However, more benign chemicals, in some cases, can reduce the efficiency of stimulation and may require additional wells, re-stimulation, cost and/or lower ultimate recovery from the well, and, therefore, increase the environmental footprint associated with development.	

Page	Section	Report Citation	Comment	References
18	2.1.4	For this study, “flowback” is the fluid returned to the surface after hydraulic fracturing has occurred, but before the well is placed into production, while “produced water” is the fluid returned to the surface after the well has been placed into production.	EPA has made an arbitrary distinction between produced water and flowback. Produced water is all water that is returned to the surface through a well borehole. Flowback process water should be considered a subset of produced water returned during the flowback process. The only factor that is used in defining this subset of produced water is the time period in which the water is returned to the surface through the well borehole. It is inappropriate and unnecessary to use the term “flowback” to differentiate produced water quality.	
19	2.1.4.	What is the composition of hydraulic fracturing wastewaters, and what factors might influence this composition?	Produced water characteristics vary significantly temporally within, and spatially among, basins, formation, and wells. EPA does not appear to have captured the breadth of these variations within the agency’s current plan. The characteristic of produced water have been studied significantly by USGS. a. Analytical techniques used to characterize produced water must be robust to the matrix interferences caused by high TDS. b. Benzene, ethyl benzene, toluene, and xylenes are the most frequently detected VOCs in shale gas produced water, and are naturally occurring. c. Industry Participation in Collaborative Groups i. Brine Chemistry Consortium – 20 + years ii. Shale Water Research Center - New group (1 year)	http://energy.cr.usgs.gov/prov/prodwat/ http://www.epa.gov/hfstudy/producedformationwatersampleresultsfromshaleplays.pdf http://www.brinechem.rice.edu/partners.cfm http://www.shalewatercenter.com/
19	2.1.4	What are the chemical, physical, and toxicological properties of hydraulic fracturing wastewater constituents?	Context regarding constituent concentration and risk of exposure, including a description of existing barriers, should be provided when discussing fracturing fluid and produced water properties.	
19	2.1.4	If spills occur, how might hydraulic fracturing wastewater contaminate drinking water resources?	Current state and federally regulations should be considered when answering this question. EPA’s study approach does not appear to acknowledge state, local, and oil and gas industry plans, procedures and/or actions to respond and control leaks and/or releases. In the rare occurrence of an unintentional environmental release, industry members act appropriately in conjunction with local authorities and in accordance with regulatory requirements to limit the impact on the environment and ensure the health and safety of the public. Not considering this fact will undoubtedly result in conclusions that are misrepresentative and misleading.	
19	2.1.5	[produced water] is generally managed through disposal into deep underground injection control (UIC) wells, treatment followed by discharge to surface water bodies, or treatment followed by reuse.	The disposal of produced water to POTWs is very rare, if used at all, for unconventional oil and gas operations. The utilization of this option should be managed on a case-by-case basis with a firm understanding of the plant’s efficiency in removing appropriate compounds. Efficiency of all treatment processes are influenced by technological and operational factors. This context should be incorporated in to the study design; specifically, the interpretation of laboratory experiments.	

Page	Section	Report Citation	Comment	References
21	2.2.	Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.	EPA's definition of EJ and the inclusion of the topic within this research implies that the agency considers this research a direct component of environmental laws, regulation, and/or policy development.	
21	2.2.	Environmental Justice	The June 13, 2011 QAPP stated that the project would be completed by August 2011 (4 months prior to the finalization of the study plan). There is no reference to this study or status. This appears to be indicative that EPA was premature to include Environmental Justice in this study.	EJ QAPP: http://www.epa.gov/hfstudy/environmental-justice-analysis.pdf
22	2.2.	Nationwide data on the locations of water withdrawals and wastewater treatment associated with hydraulic fracturing activities are difficult to obtain. The EPA was not able to identify comprehensive data sources that identify the locations of water withdrawals associated with hydraulic fracturing or facilities receiving hydraulic fracturing wastewaters.	EPA has acknowledged significant limitations regarding the ability to use this information to achieve the agency's research objectives. The agency should have understood and evaluated these databases and associated limitations during a systematic planning process (e.g. DQO) prior to implementing research activities and allocating significant finite resources. The "Data Acceptance Criteria" identified in EPA's HF Surface Spill Data Analysis QAPP (9 pages, Rev 0 Approved August 6, 2012) does not appear to be adequate for a highly influential scientific assessment. In addition the "Data Acceptance Criteria" (i.e., timeliness, comparability, and completeness) is not consistent with assessment factors used within the literature review QAPP to assess data quality (i.e., soundness, applicability and utility, clarity and completeness, uncertainty and variability, and evaluation and review).	
22	2.2.	The county-level resolution provided by the service company data set is insufficient for determining whether hydraulic fracturing activities are occurring in communities that possess characteristics associated with environmental justice populations. Finer resolution is needed since counties can contain a multitude of communities, townships, and even cities, with diverse populations.	The RFI EPA sent to the service companies in September 2010 (over a year prior to the finalization of the study plan), did not specifically request this information. This is a clear example why all research, especially a highly influential scientific assessment, should undergo a systematic planning process (e.g., DQO development) prior to implementation.	
25	3	Analysis of Existing Data	FracFocus is the best existing data source for HF fluid compositions. It is strongly recommended EPA evaluate all data within appropriate temporal and spatial context. All historic data collected - including that obtained during EPA's RFI processes - should be analyzed in the appropriate context, accounting for continuous industry practice and state regulatory improvements that evolve as both parties use their operational experience to innovate and strive for the common goal of maximizing production while ensuring protection of the environment and health and safety of personnel and the public. The development and application of hydraulic fracturing additives that can perform effectively when	

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			produced water or alternative water sources are used in stimulation fluids can reduce fresh water use. Operators and service companies continue to develop and apply environmentally conscious chemical additives and fracturing fluids mixtures on a case-by-case basis. Intellectual property right protection can have a significant impact on corporate incentives to develop technologies in these areas.	
25	3.1.	Literature Review	It is strongly recommended that EPA use the wealth of information contained in the full range of peer reviewed publications, including industry references and sources (e.g., OnePetro). In addition, evaluations of peer reviewed publications should be conducted prior to use; specifically, peer review publications that have received significant criticism within the scientific community (e.g., Osborne, 2011). In addition, the work and expertise of other federal agencies and credible stakeholders should be incorporated into the study as appropriate.	
27	3.1.3.	Principal investigators on this project are responsible for deciding whether to include these data and providing all available background information in order to place these results in the appropriate context.	The "Reference Evaluation" Excel file discussed in EPA's Data and Literature Evaluation QAPP (September 4, 2012 revision 0; 10 months after the final study plan) should be provided to peer reviewers and the public during the results peer review process. EPA should provide the SAB Panel and public with the "Reference Evaluation" Excel file that was used to develop the study plan and project plans.	Lit Review QAPP: http://www.epa.gov/hfstudy/pdfs/literature-review-qapp.pdf
27	3.1.4.	The chemical composition of flowback and produced water from hydraulically fractured formations is similar to that of conventional reservoirs	EPA has made an arbitrary distinction between produced water and flowback. Produced water is all water that is returned to the surface through a well borehole. Flowback process water should be considered a subset of produced water returned during the flowback process. The only factor that is used in defining this subset of produced water is the time period in which the water is returned to the surface through the well borehole. It is inappropriate and unnecessary to use the term “flowback” to differentiate produced water quality.	
27	3.1.4.	Water Acquisition	It is concerning that EPA has not referenced or considered incorporating state water planning processes or reports within the literature review portion of the agency's research. Water use should be investigated holistically considering all water users; similar to state water planning processes. The oil and gas sector is a relatively small water user when compared to total water use. It is unclear how water quantity and quality impacts will be attributed to oil and gas operations, specifically hydraulic fracturing, within EPA’s research given the connectivity between all water users and water resources.	Texas 2008: 0.003% (57 k acre-feet) and 0.002% (35.8 k acre-feet) of the total water use was O&G and hydraulic fracturing, respectively. (http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-RRC.pdf) Texas 2010: Mining, which includes but is not limited to the oil and gas sector, made up 1.8% of the total state water use. (http://www.twdb.state.tx.us/waterplanning/waterusesurvey/estimates/) Colorado 2010: 0.08% (13.9 k acre-feet) of the total state

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				water use was hydraulic fracturing. (http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf) Oklahoma 2012: Oil and gas drilling and fracing accounts for a very small fraction (less than 1%) of freshwater use in Oklahoma. (http://oklahomawatersurvey.org/d1/wp-content/uploads/2012/10/04-OGS.pdf)
27	3.1.4.	Water Acquisition	Regional, state and local water regulators appropriately allocate all water rights and respond to short-term and long-term local environmental conditions during as part of their management of water resources. This context should be incorporated in to the study design to avoid unrealistic results; specifically, the scenario models must consider the existing regulatory structure (e.g., private property right issues associated with water rights), as well as operational boundaries. a. Regulatory agencies take action to prioritize water resources, including temporarily halting oil and gas withdrawals (e.g., SRBC, TX). b. LA Cooperative Endeavor Agreement / Plan of Water Use requires a demonstration to the DNR that the water use does not unreasonably interfere with any other use of the water presently, or which may legally and reasonably be anticipated, for purposes including public consumption, agriculture, industrial uses, and recreation.	http://www.tceq.texas.gov/response/drought http://dnr.louisiana.gov/assets/docs/11DRAFT-Water-Application.pdf
27	3.1.4.	The literature review is currently underway. Water acquisition, chemical mixing, and flowback and produced water are the only stages of the hydraulic fracturing water cycle for which specific updates are available at this time.	EPA did not provide any literature review progress in the areas of injection or treatment/disposal. Literature review should be the first phase of any research initiative and field/laboratory activity should not be implemented prior to a significant portion of this research phase.	
28	3.1.4.	Information on volumes and sources of water in the Bakken Shale comes largely from news articles.	EPA should not be considering media references within this highly influential study.	
28	3.1.4.	Chemical Mixing	It appears that EPA has not considered investigating the concentration of chemical components within the scope of this study. It is highly recommended that the agency include this context within the research. The ultimate goal of hydraulic fracturing is to stimulate the unconventional reservoir in order to recover hydrocarbons in the most efficient manner possible. The composition of frac fluids and associated chemical additives used are fit for purpose given the specific well bottomhole temperature, executional factors (such as pumping rate), local factors (such as	

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			mix-water quality), and desired fracture geometry (wide, biwing fractures, versus narrow, complex fractures). More benign chemicals could be less efficient and fracturing fluids may require additional wells, stimulation, cost and/or lower ultimate recovery from the well.	
30	3.1.4	Papers describing impacts from spills of produced water from conventional oil and gas production wells are being considered as part of the literature review because the chemical composition of flowback and produced water from hydraulically fractured formations is similar to that of conventional reservoirs (Hayes, 2009).	HF occurs in both conventional and non-conventional resource plays. It appears that EPA is not acknowledging this fact.	
30	3.1.4.	Chemicals commonly used in hydraulic fracturing fluid are ubiquitous, a very large numbers of papers have been found.	The general composition of HF additives is known. MSDSs contain information that is necessary to understand potential health and safety hazards. HF chemical additive constituents are found in common household products. A research focus should be placed on known major constituents, and not investigation of trace elements and impurities. Additionally, there are opportunities for improvement regarding the development of analytical methods associated with testing additives.	http://www.same-satx.org/briefs/120410-holditch.pdf
31	3.2.	Spills Database Analysis	“Reported” or “potential” spills that have not been confirmed/validated should not be considered reliable data for a risk (likelihood and severity) analysis. For example, tip or complaint lines should not be considered appropriate data resources. Caution needs to be taken when evaluating spill databases to ensure accuracy, consistency, and comparability of reported spills, including the appropriate segregation of spill types (e.g., solids or liquids) and ensuring spills that were reported by more than one entity are captured once in the analysis. Spills related to auxiliary activities and/or processes (e.g., pipelines) should not be included in this evaluation because it is not within the scope of the study.	

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32	3.2.3.	There is currently no national repository or database that contains spill data focusing primarily on hydraulic fracturing operations.	Potential risks to drinking water from spills are not specific to those associated with hydraulic fracturing. National and state databases are fit for their intended purposes in terms of being generalized to include spills from all industrial and/or anthropogenic activities. EPA should not attempt to assess current databases on the basis of their ability to fulfill the agency's current research objectives. Rather, the agency should have understood and evaluated these databases and associated limitations during a systematic planning process (e.g. DQO) prior to implementing research activities and allocating significant finite resources.	
32	3.2.3.	The search timeframe is limited to incidents between January 1, 2006, and April 30, 2012	It is recommended that EPA expand the timeframe of FracFocus data acquisition and evaluation to ensure more current information is provided in the 2014 report of results.	
34	3.2.4.	This information is often based on the estimates made by persons responding to a spill and may be incomplete. More accurate information may be available once a response is complete, but this database is not updated with such information.	EPA has acknowledged significant limitations regarding its ability to use this information to achieve the agency's research objectives. The agency should have understood and evaluated these databases and associated limitations during a systematic planning process (e.g. DQO) prior to implementing research activities and allocating significant finite resources. The "Data Acceptance Criteria" identified in EPA's HF Surface Spill Data Analysis QAPP (9 pages, Rev 0 Approved August 6, 2012) does not appear to be adequate for a highly influential scientific assessment. In addition the "Data Acceptance Criteria" (i.e., timeliness, comparability, and completeness) is not consistent with assessment factors used within the literature review QAPP to assess data quality (i.e., soundness, applicability and utility, clarity and completeness, uncertainty and variability, and evaluation and review).	Spill QAPP: http://www.epa.gov/hfstudy/pdfs/hf-spills-analysis-qapp.pdf Lit Review QAPP: http://www.epa.gov/hfstudy/pdfs/literature-review-qapp.pdf
36	3.2.4.	The database containing information regarding contamination of ground water due to pits tracks only the current company, facility name, tracking number, county, location, and status of the contamination incidents. Details regarding the contamination incident and the relation of the event to hydraulic fracturing are not included. Additional research is needed to determine if the pit information is related to hydraulic fracturing.	EPA has been tasked with investigating potential impacts of HF, which is a specific step in the process of developing unconventional oil and natural gas. When the Agency references or reports information that it has not confirmed is related to the HF phase of development, it is both confusing and misleading to the public. The agency should refrain from publishing information that has no applicability to the Congressional scope of the study and that the potential to mislead the public. Precise use of terminology is critical as the public looks to the government as a definitive source of information.	

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38	3.2.5.	The spills database analysis has several important limitations: Potential underreporting...Variation in reporting requirements for different sources...The lack of electronic accessibility of some state-reported data on oil and gas-related spills and emergency responses.	The limitations EPA has identified regarding variation and electronic accessibility should be interpreted as deficiencies in the agency's study planning and design, not necessarily the databases.	
40	3.3.3.	Research Approach	The "Quality Objectives and Criteria" identified in EPA's Analysis of Data Received by Service Company QAPP (14 pages, Rev 0 Approved September 1, 2012) does not appear consistent with assessment factors used within the literature review QAPP to assess data quality (i.e., soundness, applicability and utility, clarity and completeness, uncertainty and variability, and evaluation and review).	Service Company Data QAPP: http://www.epa.gov/hfstudy/pdfs/qapp-service-company.pdf Lit Review QAPP: http://www.epa.gov/hfstudy/pdfs/literature-review-qapp.pdf
41	3.3.3.	information… being assembled…Concentration of each chemical in each fluid product	The agency should include date of use and chemical concentration within the fracturing fluid. EPA should integrate the context of concentration information throughout the agency's research.	
47	3.4.3.	Well File Selection. The EPA used a list of hydraulically fractured oil and gas wells provided to the agency by the nine hydraulic fracturing service companies (referred to hereafter as the "service company well list") to select 350 specific well identifiers associated with nine oil and gas operators.	A sample size of 350 wells is a relatively small dataset and does not appear to be statistically significant or representative. Roughly 1.4 percent of wells and less than one percent of operators. The lack of a comprehensive program to determine representative wells would automatically introduce unintentional biases.	
53	3.4.4.	The EPA is creating queries on the extracted data that are expected to determine whether drinking water resources were protected from hydraulic fracturing operations.	Determination of protection appears to be outside EPA's stated study scope - the identification of factors - and more aligned with an enforcement initiative.	
54		Distances between wells hydraulically fractured and geologic faults	Any research or reports that reference faults should be conducted and referenced in the appropriate contexts. For example, the existence of a fault does not mean that it is transmissive and/or extends to drinking water resources.	
54	3.4.5.	Statistical Analysis. Once the data analysis has been completed, where possible, extrapolation of the results will be performed to the sampled universe of 24,925 wells	Statistics without context and appropriate assumptions could be extremely misleading. For example, spatial and temporal relationships should not be considered the sole bases for conclusions.	

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55	3.5.2.	This analysis is gathering information on water and chemical use in hydraulic fracturing operations and attempts to answer the following questions:	EPA does not appear to be leveraging the full potential of this data source. For example, trends in chemical use and fracturing fluid concentrations are not included in EPA's questions.	
55	3.5.2.	What are the different sources of water reported in FracFocus, and is it possible to determine the relative proportions by volume or mass of these different sources of water?	Caution should be used when relying on FracFocus for water types. There is the potential that the term “fresh” is used not to signal that it came from a new water source compared to being recycled, but to signify that it does not have chemicals added to it yet. (this pertains to statements on page 59 as well)	
56	3.5.3	It is beyond the scope of the project to evaluate the quality or representativeness on a national scale of the data submitted to FracFocus by oil and gas operators.	EPA should fully understand the quality and representativeness of all information it utilizes to draw research conclusions.	
57	3.5.3.	Figure 13. Example of data disclosed through FracFocus	EPA's disclosure example is not representative and is misleading in terms of make-up and concentrations.	
59	3.5.4.3.	Data Analysis - Water Acquisition	The approach EPA is proposing to determine the volume of water utilized in HF operations could lead to inaccurate results. While “total water” is given on the FracFocus reports in gallons, the only case in which an accurate assessment of the type of water used in HF operations can be determined is if the operator indicates in the breakout section that the only water source used was “fresh water.” Then and only then can the assumption of 8.35 lb / gal (water density) be used to reverse calculate the volume of “fresh water” used in the completion. If any other type of “non-fresh water” albeit brackish, recycled, or produced water is used in the completion, without a mass provided for each water type, it’s not possible to determine accurate volumes based on total water mass and percentages of each water type alone. The reason for this is the density of brine is different than fresh water and will cause variation in the data. It is recommended that EPA not use this approach to calculate total volume of water or HF chemicals used.	

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62	4.1.	Subsurface Migration Modeling	All models must include all assumptions and any sensitivity analysis. It is critical to apply an appropriate physical model to evaluate the transport of tracers and the effect of injection pulses on flow in reservoirs and toward the surface. a. Models must not apply standard hydrogeologic approaches that treat the entire subsurface as a fully interconnected pore space that does not honor the physical reality of the horizontal and vertical transport properties in such strata. Most consolidated clastic rocks in sedimentary basins are highly layered systems with (1) widely varying horizontal permeabilities in the different layers and (2) more importantly, much lower vertical permeabilities – often orders of magnitude lower. It is these low vertical permeabilities, along with capillary pressure and clay/water interaction among other factors that form what is commonly known as a caprock that traps the hydrocarbons in place and creates reservoirs. Such a "sandbox" approach is highly inappropriate for modeling the effect of subsurface operations/processes on near-surface layers. b. There are available reservoir simulators that can be used to perform the modeling, and these should be populated with realistic transport parameters that are accepted by petroleum scientists. c. Assessment of "What If" scenarios will lead to an inaccurate "convection" or whatever the modeler puts in as worst case. As such, these scenarios become useless to describe what may really happen in a well and describe only the modeler's imagination. d. EPA's guidelines on building, applying, calibrating, and analyzing the results from models must be honored in this highly influential scientific assessment.	http://www.epa.gov/sab/panels/cremgacpanel.html
62	4.1.	Lawrence Berkeley National Laboratory (LBNL), in consultation with the EPA, will simulate the hypothetical subsurface migration of fluids (including gases) resulting from six possible mechanisms using computer models. The selected mechanisms address the research questions identified in Table 26.	It is not apparent how this research will be able to answer "how effective are current well construction practices at containing gases and fluids before, during, and after fracturing?"	
62	4.1.	The segment of the population that receives drinking water from private wells may be especially vulnerable to health impacts from impaired drinking water. Unlike water distributed by public water systems, water from private drinking water wells is not subject to National Primary Drinking Water Regulations, and water quality testing is at the discretion of the well owner.	This statement acknowledges a general risk to private well owners that is not specific to hydraulic fracturing. Undoubtedly, these risks will be highlighted during EPA's research, however, it should not be assumed that elevated parameters are attributable to oil and gas development. It is important to describe the baseline health risks regarding drinking water. Private drinking water wells are subject to poor installation, maintenance (e.g., well disinfection) and operations. Additionally many are contaminated inadvertently by poorly placed septic systems and storm water run in.	

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62	4.1.	Lawrence Berkeley National Laboratory (LBNL), in consultation with the EPA, will simulate the hypothetical subsurface migration of fluids (including gases) resulting from six possible mechanisms using computer models.	Scenarios and assumptions are not presented in enough detail within the study plan, progress report or LBNL Modeling QAPP to guide this highly influential research or inform peer reviewers. All presented scenarios are based on multiple barriers failing. The most valuable scenario and the one missing from LBNL/EPA's research is a **no failure scenario**. **Operational practice and response** do not appear to be factored into the model. For example, monitoring annular casing pressure during HF allows for the processes to be halted when abnormal conditions are observed.	LBNL Modeling QAPP: http://www.epa.gov/hfstudy/QAPP_LBNL_analysis%20of%20HF%20Final%2020111201%20unsigned_508_km.pdf
64	4.1.1.	Figure 14: Scenario A	There is not representation of the intermediate and surface strings of casing/cement, which protect the groundwater aquifer and other potential shallow hydrocarbon and natural resource zones. The figure is an unrealistic conceptual model of inadequate cement and fractured cement. Any competent cement along the wellbore would effectively seal gas from migrating vertically, similar to a plug.	
65	4.1.1.	Figure 15: Scenario B1	Propagation of fractures from target formation to surface, or 1,000 meters vertically such as shown, is not representative. Multiple peer-reviewed papers discuss the impossibility of such based on stress fields and overburden, such as described in Carter et al., 2013. Natural fractures/faults below 1,000' depth are noted as healed, not open conduits, based on calcite fill observed in cuttings and cores, and would have bled off the gas from the target formation over geologic time, which is not the case.	http://www.pcpg.org/Resources/Documents/Shale%20Gas/PAGS%20PCPG%20Rebuttal%20to%20Frac%20Induced%20GW%20Contamination%20Article%201.pdf
66	4.1.1.	Figure 16: Scenario B2	See comments on Figure 15. The fracture would not continue to propagate vertically to surface since the fracture eventually intersects a porous zone, at which point the pressure would drop and the fracture would terminate due to fluid diffusion in a porous medium.	
67	4.1.1.	Figure 17: Scenario C	See comments on Figure 15.	
68	4.1.1.	Figure 18: Scenario D1 Figure 19: Scenario D2	Illustrations do not show the lateral distance to the offset well, which is avoided during planning. Figure 14 comments apply.	

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70	4.1.2.	This research project does not assess the likelihood of a hypothetical scenario occurring during actual field operations.	This research has little value regarding informing the public and decision makers without the context of likelihood. In addition, statements found in EPA's progress report conflict with the QAPP associated with this research. LBNL Modeling QAPP (approved on 12/06/2011) includes the evaluation of likelihood of occurrence of the hypothetical failures. In addition, EPA's study approach does not appear to acknowledge state, local, and oil and gas industry plans, procedures and/or actions to respond and control leaks and/or releases. In the rare occurrence of an unintentional environmental release, industry members act appropriately in conjunction with local authorities and in accordance with regulatory requirements to limit the impact on the environment and ensure the health and safety of the public. Not considering this fact will undoubtedly result in conclusions that are misrepresentative.	LBNL Modeling QAPP: http://www.epa.gov/hfstudy/QAPP_LBNL_analysis%20of%20HF%20Final%2020111201%20unsigned_508_km.pdf
73	4.1.2.	Uncertainty in the data will be addressed by first analyzing base cases that involve reasonable estimates of the various parameters and conditions and then conducting sensitivity analyses that cover (and extend beyond) the possible range of expected values of all relevant parameters.	Modeling subsurface phenomena is extremely complex and must consider a range of broad uncertainty; it appears unlikely EPA will have adequately addressed the broad uncertainty or be able to achieve appropriate model calibration with integrated holistic data-sets, and as such conclusions based on models will not be robust representations for policy or regulatory decision making.	LBNL Modeling QAPP: http://www.epa.gov/hfstudy/QAPP_LBNL_analysis%20of%20HF%20Final%2020111201%20unsigned_508_km.pdf
74	4.1.3.	Results from this work are being analyzed and will be published when complete.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each and the projected timeline for review completion.	
74	4.1.3.	As illustrated in Figure 15, the simulated system is composed of a 100-meter thick aquifer (from 100 to 200 meters below the surface), a fracture extending from the bottom of the gas reservoir at 1,200 meters below surface to the base of the aquifer, which is 1,000 meters above the gas reservoir.	The depths of wells being simulated are not representative of typical depth to shale.	

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76	4.2.2.	In Pennsylvania, however, wastewater has been treated in wastewater treatment facilities (WWTFs), which subsequently discharge treated wastewater to surface water bodies.	The disposal of produced water in POTWs is very rare, if used at all in a given area, for unconventional oil and gas operations. The utilization of this option should be managed on a case-by-case basis with a firm understanding of the plant's efficiency in removing appropriate compounds. Efficiency of all treatment processes are influenced by technological and operational factors. This context should be incorporated in to the study design; specifically, the interpretation of laboratory experiments. a. PA DEP reported for the first 6 months of 2012 0 bbls of produced water (formation or flowback fluids) from unconventional wells were disposed in POTWs. b. PA DEP reported for the first 6 months of 2012 1,174 bbls (0.01% of total) of produced water (formation or flowback fluids) from unconventional wells were disposed in Commercial Treatment Systems.	PA DEP Reference: https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/ExportWasteData.aspx?PERIOD_ID=2012-1
77	4.2.3.	The results of the mass balance model simulate possible impacts during a large volume, high concentration discharge without natural attenuation of contaminants. The empirical model and a hybrid empirical-numerical model estimate impacts in a more realistic setting with variable chemical concentrations, discharge volumes, and flow rates of the receiving surface water.... the steady-state mass balance model may be too conservative (by providing larger concentration estimates) to accurately represent downstream concentrations of chemicals.	EPA has acknowledged that the simplicity of the mass balance model and assumptions are unrealistic. Providing this analysis to the public and decision makers would only mislead them. For this reason, it is recommended that the mass balance model not be included in reports of results.	
78	4.2.3.	Hybrid Empirical-Numerical Model Estimates Impacts for River Networks...Using these approaches provides improved accuracy in the simulation results. The EPA will prepare a user's guide to the model and make both the computer model and user's guide widely available for duplicating the results prepared for this project and for more general use.	EPA should make this model and user guide available to the public and peer reviews in advance of releasing model results.	
79	4.2.5.	A description of the EPA-developed empirical-numerical model and application of the empirical-numerical and mass balance models to tracer experiments is being developed by EPA scientists and are expected to be submitted for publication in a peer-reviewed journal. The results from testing of the models and the analysis of the WWTF effluent data will be included in another peer-reviewed journal article.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each and the projected timeline for review completion.	

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80	4.3.	Table 29. Research questions addressed by modeling water withdrawals and availability in selected river basins	Consultation with regional, state, and local water regulators, as well as industry within diverse areas, is critical during this research due to the variability in local environmental conditions and present considerable difficulty in the current national research approach.	
80	4.3.1.	The volume of water needed for well drilling is understood to be much less, from 60,000 gallons in the Fayetteville Shale to 1 million gallons in the Haynesville Shale (GWPC and ALL Consulting, 2009). Water-based mud systems used for drilling vertical or horizontal wells generally require that freshwater (non-potable, potable, or treated) be used as makeup fluid, although wells can also be drilled using compressed air and oil-based fluids.	Drilling is outside the scope of the study. EPA should refrain from including information, within deliverables, that is not associated with the scope of the study because it has the potential to mislead the public.	
89	4.3.2.	SWAT is an appropriate choice in the less data-rich UCRB, where hydrological response units can be parameterized based on publicly available GIS maps of land use, topography, and soils.	Given the insignificant use of fresh water in UCRB for the HF process, it appears EPA has stepped outside the scope ("HF water life-cycle") of the study to investigate land use (i.e., pad constructions). The model does not appear to account for discharge benefits. The focus of the study seems to be very negative and the benefits are not included. It is recommended that EPA not expand the scope of the UCRB research beyond the HF process and incorporate benefits into the research on this topic.	
90	4.3.2.	Modeling Future Scenarios…three separate scenarios will be simulated: business-as-usual, energy plus, and green technology...water use will be assessed across a range of weather conditions (i.e., drought, dry, wet, and very wet years based on the historical record).	There appear to be significant flaws in EPA's identified scenarios and associated assumptions. For example, the model does not appear to take into consideration local regulatory authority to prioritize water use during drought conditions and operational practices to acquire/store water during the wet season. The modeling also does not appear to account for opportunities for use of water under existing water use permits. Two additional scenarios that would be of value and should be included in the analysis are a no HF activity and low HF activity scenario. These scenarios would provide the appropriate context necessary to understand the relative influence of HF on water availability. In addition, the use of the term "green technologies" is concerning, in some cases conventional water management could be the “greenest” alternative from a holistic perspective.	

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92	4.3.2.	In the UCRB, 100% recycled water use is typical for hydraulic fracturing of tight sandstones (personal communication, Jonathan Shireman, Shaw Environmental & Infrastructure, May 7, 2012). Surface water is acquired for well drilling and cementing (0.18 million gallons), dust abatement (0.03 million gallons), and hydrostatic testing (0.04 million gallons) only (US FWS, 2008). Per well surface water use in the UCRB business as usual and energy plus scenarios will therefore be 0.25 million gallons. For the UCRB green technology scenario, surface water will be assumed to be acquired for well drilling and cementing only (0.18 million gallons per well).	Given the insignificant use of fresh water in UCRB for the HF process, it appears EPA has stepped outside the scope ("HF water life-cycle") of the study to investigate drilling and cementing, dust abatement, and hydrostatic testing. It is recommended that EPA not expand the scope of the UCRB research beyond the HF process.	
92	4.3.3.	The models are being calibrated and validated. The future scenarios are being designed, with model simulations to follow. Work is underway and will be published in peer-reviewed journals when completed.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each and the projected timeline for review completion.	
95	5.1.2.	High TDS levels—including bromide and chloride—have been detected in the Monongahela River in 2008 and the Youghiogheny River in 2010 (Lee, 2011; Ziemkiewicz, 2011). The source and effects of these elevated concentrations remains unclear.	EPA should review references and databases with historic/pre-HF water quality information to determine if the water quality has significantly changed in these areas.	
98	5.1.3.2.	These models have previously been used to evaluate a wide range of environmental data for air, soil, and sediments (Cao et al., 2011; Pancras et al., 2011; Soonthornnonda and Christensen, 2008), and are now being used for emerging issues, such as potential impacts to drinking water from hydraulic fracturing.	All research products should be considered highly influential and subject to the Data Quality Act and OMB's Guidance. The "individual reports" and papers is a new concept for the EPA HF Study. EPA should publish a list of all individual reports and papers, the peer review plan for each and the projected timeline for review completion.	
99	5.1.4.	Median concentration of selected chemicals and conductivity of effluent treated and discharged from two wastewater treatment facilities that accept oil and gas wastewater.	It appears EPA did not confirm that when the samples were taken that the facilities were discharging oil and gas treated wastewater. Additionally at this time operators were no longer sending HF flowback/produced water to wastewater treatment facilities.	

Page	Section	Report Citation	Comment	References
103	5.2.2.2.	The exact number of POTWs currently accepting hydraulic fracturing wastewater is not known.	It is concerning that EPA is expending significant resources in an area that the agency has not properly assessed. This statement brings into question EPA's original risk-based prioritization for the study plan development. One would expect the number of POTWs to be a key input into that process. Study Plan citation: "Following guidance from the SAB, EPA used a risk-based prioritization approach to identify research that addresses the most significant potential risks at each stage of the hydraulic fracturing water lifecycle. The risk assessment paradigm (i.e., exposure assessment, hazard identification, dose-response relationship assessment, and risk characterization) provides a useful framework for asking scientific questions and focusing research to accomplish the stated goals of this study, as well as to inform full risk assessments in the future."	EPA HF Study Plan: http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hf_study_plan_110211_final_508.pdf
104	5.2.2.3.	Gas producers are accelerating efforts to reuse and recycle hydraulic fracturing wastewater in some regions in order to decrease costs associated with procuring fresh water supplies, wastewater transportation, and offsite treatment and disposal.	This statement misleads the public to conclude that cost is the only driver in a producer's decision to reuse water. This is particularly disconcerting given the industry efforts to educate the agency on our operations. Cost is definitely a factor, but not the only one. Industry strives for continuous improvement in terms of understanding local water availability, publically disclosing water use and prudent fresh water use/reduction practices. These efforts are driven by stewardship, environmental/corporate risk reduction and economics. A number of complex operational, logistical, environmental, health, safety and economic factors/risks require evaluation prior to the implementation of fresh water use/reduction practices. These factors require case-by-case analyses and should not be generalized in the study. The application of recycling and reuse technologies has reduced fresh water use in specific areas. However, it requires acknowledgement that there is not a "one size fits all" technology that can be applied across all developments, and evaluation of this practice and alternative technologies should be conducted on a case-by-case basis using a holistic approach (e.g., logistics, water-energy nexus).	http://www.shalegas.energy.gov/resources/HF2_e1.pdf Luedecke, R. "Devon's Water Sustainability Initiatives – Technologies and Policies to Reduce Shale-Related Impacts" 2012 The Nature Conservancy Reducing Energy's Impacts to Water and Biodiversity Conference, July 12, 2012.
104	5.2.3.	The EPA is examining the fate and transport of chemicals through conventional POTWs treatment processes and commercial chemical coagulation/settling processes.	The context regarding fate, transport and exposure should be provided within all EPA research deliverables, however, currently appears to be lacking throughout the study.	
105	5.2.3.	Microbial community health will be monitored in the reactors to identify the point where biological processes begin to fail.	Microbial community health can be impacted by numerous factors. Microbes have the ability to adapt to the extreme conditions. EPA's research has not been designed appropriately to capture these complexities.	

Page	Section	Report Citation	Comment	References
106	5.2.4.	Water Treatability Studies - This research is currently in the planning stage.	Given the technical concerns and the limited progress regarding this research activity, EPA should consider removing it from the scope of the study.	
108	5.3.1.	As a first step, this project is examining the formation of brominated THMs, including bromoform (CHBr3), dibromochloromethane (CHClBr2), and bromodichloromethane (CHCl2Br), during drinking water treatment processes. The formation of haloacetic acids (HAAs) and nitrosamines during drinking water treatment processes is also being investigated. 64 Nitrosamines are byproducts of drinking water disinfection, typically chloramination, and currently unregulated by the EPA. Data collected from the second Unregulated Contaminant Monitoring Rule indicate that nitrosamines are frequently being found in PWSs. Nitrosamines are potentially carcinogenic.	The formation of these compounds is not unique to HF, therefore, EPA should consider removing this research the HF Study.	
112	5.4.	Sample analysis is an integral part of the EPA's Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources (US EPA, 2011e) and is clearly specified in research plans being carried out for the study's retrospective case studies, prospective case studies, and laboratory studies. The EPA requires robust analytical methods to accurately and precisely determine the composition of hydraulic fracturing-related chemicals in ground and surface water, flowback and produced water, and treated wastewater.	All analytical methods should have been developed in advance of implementing them in HF study laboratory/field activities.	

Page	Section	Report Citation	Comment	References
112	5.4.2.	The analytical methods chosen must undergo rigorous testing, verification, and potential validation to ensure that the data generated they generate are of known and high quality.	The use of key indicator compounds (TDS, Cl, and divalent cations) is the most reliable, efficient, and cost effective method for initial scientific investigations for potential or know produced water releases. The concentration of VOCs and SVOCs in shale gas produced water are generally too low for use as indicator compounds. The concept of indicator compounds in the environmental field is well established (e.g., Ohio, Louisiana, Oklahoma, Arkansas, California, Texas, etc.).	http://www.epa.state.oh.us/portals/30/rules/DI-033.pdf http://www.deq.louisiana.gov/portal/Portals/0/RemediationServices/APPENDIXD.pdf http://www.occeweb.com/rules/Chapter%2029%20Effective%207-1-09%20SOS.pdf http://www.adeq.state.ar.us/hazwaste/branch_tech/pdfs/tph_sls_web_version.pdf http://www.dtsc.ca.gov/AssessingRisk/upload/HHRA-Note-4.pdf http://www.tceq.texas.gov/publications/rg/rg-366_trrp_27.html
113	5.4.3.1.	The following criteria were developed to identify a subset of the chemicals listed in Appendix A for initial analytical method testing activities: • Frequency of occurrence in hydraulic fracturing fluids and wastewater • Toxicity • Mobility in the environment (expected fate and transport) • Availability of instrumentation/detection systems for the chemical	Uniqueness to HF should have been a criterion. An appropriate screen would include a complete analysis to determine if HF is involved, then potential exposure should be considered, and then and only then should toxicity be reviewed.	
118	5.4.4.1.	Glycols (diethylene glycol, triethylene glycol, and tetraethylene glycol) and the chemically relatedcompounds 2-butoxyethanol and 2-methoxyethanol are frequently used in hydraulic fracturing fluids and not naturally found in ground water. Thus, they may serve as reliable indicators of contamination of ground water from hydraulic fracturing activities.	Glycols may be found in HF fluids, however, these chemical are ubiquitous. For example, they are used in food products, laboratory preservatives and water well construction materials.	
122	6	Toxicity Assessments	The development and application of hydraulic fracturing additives that can perform effectively when produced water or alternative water sources are used in stimulation fluids can reduce fresh water use. In addition, some additives serve an important role in protecting well integrity. A focus on toxicity without an understanding of why the chemical is used and the potential environmental benefits should be avoided. Intellectual property right protection can have a significant impact on corporate incentives to develop technologies in these areas.	

Page	Section	Report Citation	Comment	References
129	7.1.1.	Table 50. General approach for conducting retrospective case studies. The tiered approach uses the results of earlier tiers to refine sampling activities in later tiers.	EPA has not provided the specific tier that each retrospective studies is currently under. Nor has the agency identified a consistent methodology for determining if a retrospective study or site requires further investigation. This methodology should be spelled out and the agency should describe how each of the retrospective cases has gone through review and the conclusions reached (i.e. Tiering).	
129	7.1.1.	Tier I - Verify potential issues • Evaluate existing data and information from operators, private citizens, state and local agencies, and tribes (if any) • Conduct site visits • Interview stakeholders and interested parties	EPA has not published a QAPP for evaluating existing data and information related to the retrospective study locations. Specifically, there is no evidence that EPA has comprehensively collected and evaluated background/baseline water quality information that could be used to evaluate potential evidence of drinking water contamination is caused by HF. The EPA failed to interview operators during tier 1 activities; operators within the area of interest should have been considered stakeholders.	
129	7.1.1.	Tier 2 - Determine approach for detailed investigations • Conduct initial sampling of water wells, taps, surface water, and soils • Identify potential evidence of drinking water contamination • Develop conceptual site model describing possible sources and pathways of the reported or potential contamination • Develop, calibrate, and test fate and transport model(s)	EPA should work closely with states and operators in the retrospective study areas to develop the conceptual site model. States and operators have critical experience that would contribute to the quality of research results.	
130	7.1.1.	Table 51. Analyte groupings and examples of chemicals measured in water samples collected at the retrospective case study locations.	A number of the analytes listed in the table have methods that are being developed by the EPA. It is recommended that methods that have not been completely developed, verified, validated and approved not be used for field sampling activities.	
132	7.2.1.	Potential sources of ground water contamination under consideration include activities completion and enhancement techniques, improperly plugged and abandoned wells, gas migration, and residential impact.	The agency should not assume a potential impact has been caused by HF, therefore, investigating other potential sources of contamination and understanding background conditions and water quality variability may be necessary. However, if it is highly likely that a potential impact is not caused by HF, the agency should not expend significant project resources to perform further investigation under the jurisdiction of the study.	
138	7.3.1.	Since the blowout, the State of North Dakota has overseen site cleanup and has required the well's operator to conduct ground water monitoring on a quarterly basis.	These types of responses and associated regulations and operational plans/practices have not been taken into consideration by the EPA within the study. This context is critical to understanding the risk to drinking water and the public.	

Page	Section	Report Citation	Comment	References
143	7.4.1	If anomalies in ground water quality are found during sampling, all potential sources of contamination in the study area will be considered, including those not related to hydraulic fracturing.	The agency should not assume a potential impact has been caused by HF, therefore, investigating other potential sources of contamination and understanding background conditions and water quality variability may be necessary. However, if it is highly likely that a potential impact is not caused by HF, the agency should not expend significant project resources to perform further investigation under the jurisdiction of the study.	
143	7.4.1.	The EPA chose Bradford County, and parts of neighboring Susquehanna County, as a retrospective case study location because of the extensive hydraulic fracturing activities occurring there, coincident with the large number of homeowner complaints regarding the appearance, odor, and possible health impacts associated with water from domestic wells.	It is paramount that background, baseline and natural variation are understood, and other potential sources of contamination are considered. Starting from a known cause (i.e., operational failure or incidence), and investigating the severity of impacts on drinking water is more likely to produce reliable research conclusions and reduce uncertainty. Initiating the process at locations that have perceived drinking water impacts and attempting to trace those perceived impacts back to a hydraulic fracturing location will most likely produce unreliable conclusions and increased uncertainty.	
145	7.4.2.	Naturally high levels of TDS, barium, and chloride found in ground water make it difficult to assess the potential impacts of hydraulic fracturing activities in this part of the country since these analytes would normally serve as indicators of potential impacts. In addition, methane occurs naturally in ground water in the study area, making an assessment of potential impacts of methane due to hydraulic fracturing on drinking water resources more challenging than at other study locations.	EPA should acknowledge that the naturally occurring water characteristics could have led to false groundwater contamination allegations, which was their sole selection criterion for retrospective site selection.	
146	7.4.3.	Since methane is known to be naturally present in the ground water of northeastern Pennsylvania	Building on EPA's statement, studies using larger groundwater sample populations have proven that gas is in highly localized seep areas and is not related to natural gas development (Molofsky, 2012; Baldassare, 2012; Weston Solutions, 2012). Methane is the most common contaminant found in well water, regardless of whether there is gas drilling in the area.	
159	8.1.	All agency research projects that generate or use environmental data to make conclusions or recommendations must comply with the EPA QA program requirements...the Quality Management Plan was created to make certain that all research be conducted with integrity and strict quality controls.	EPA appears to have begun the agency's research activities in 2010, however, the revision 0 project QMP was approved Oct. 2011. Typically QMPs are developed and approved prior to beginning research activities to make certain that all research is conducted with integrity and strict quality controls. This is even more important during the conduct of a highly influential scientific assessment.	http://www2.epa.gov/sites/production/files/documents/HF-QMP-1-19-2012.pdf

Page	Section	Report Citation	Comment	References
161	8.2.	Peer review, an important part of every scientific study, is a documented critical review of a specific scientific and/or technical work product (e.g., paper, report, presentation). It is an in-depth assessment of the assumptions, calculations, extrapolations, alternate interpretations, methodology, acceptance criteria, and conclusions in the work product and the documents that support them.	EPA has provided the recently established ad hoc SAB Panel with charge questions that are not geared toward evaluating EPA's methodologies and acceptance criteria. EPA is encouraged to involve industry to provide current information and confirmation. Industry is committed to ensuring the study is based on sound science and believes that this report will verify what has been repeatedly shown – that HF performed responsibly is environmentally safe.	
170	9.3.	While the EPA expects hydraulic fracturing technology to develop between now and the publication of the report of results, the agency believes that the research described here will provide timely information that will contribute to the state of knowledge on the relationship between hydraulic fracturing and drinking water resources.	The industry and state regulatory agencies continue to improve practices and regulations associated with unconventional oil and gas development based on experience. There is concern that the study has not been designed to capture this progress. It is recommended the agency carefully review conclusions and finding within the appropriate context of current practices and regulations at the state level. a. RFI: The original data collected by EPA from Service Companies and Operators during the RFI process could be out of date (e.g., well construction and other industry practices)	
170	9.3.	The agency does not believe that the report of results will provide definitive answers on all research questions for all time and fully expects that additional research needs will be identified.	All conclusions and limitations associated with EPA's research should be disclosed within report of results and all other research deliverables.	

APPENDIX D

WESTON WILSON LETTER

October 8, 2004

Weston Wilson
EPA Employee
Denver, Colorado

Honorable Wayne Allard
7340 E. Caley, Suite 215
Englewood, Colorado 80111

Honorable Ben Nighthorse Campbell
6950 E. Belleview Avenue, Suite 200
Greenwood Village, Colorado 80111

Honorable Diana DeGette
600 Grant Street, Suite 202
Denver, Colorado 80203

Dear Senators Allard and Campbell and Representative DeGette,

Recent events at EPA have caused me and several of my peers at EPA great concern. In June of this year, EPA produced a final report pursuant to the Safe Drinking Water Act that I believe is scientifically unsound and contrary to the purposes of the law. In this report, EPA was to have studied the environmental effects that might result from the injection of toxic fluids used to hydraulically fracture coal beds to produce natural gas. In Colorado, coal beds that produce natural gas occur within aquifers that are used for drinking water supplies. While EPA's report concludes this practice poses little or no threat to underground sources of drinking water, based on the available science and literature, EPA's conclusions are unsupportable. EPA has conducted limited research reaching the unsupported conclusion that this industry practice needs no further study at this time. EPA decisions were supported by a Peer Review Panel; however five of the seven members of this panel appear to have conflicts-of-interest and may benefit from EPA's decision not to conduct further investigation or impose regulatory conditions.

As these matters are complex, I enclose a technical analysis to further inform you and other members of Congress. I invoke the protections under the First Amendment of the Constitution and the Whistleblowers Protection Act should EPA retaliate against me as a result of speaking with you or other members of Congress or speaking to the press or the public regarding this matter.

I am a resident of Denver in the first Congressional District of Colorado and I am employed by the Environmental Protection Agency in Denver. I have been employed by the EPA's Regional Office in Denver, since 1974. I am currently assigned to the Office of Ecosystems Protection and Remediation, National Environmental Policy Act (NEPA) Team. I am an environmental engineer assigned to assist EPA with its responsibilities under Section 309 of the Clean Air Act to independently review federal agency's compliance with NEPA. Currently I analyze the environmental impacts of coal mining, gold mining, and oil and gas development on public lands. I serve as the Legislative Advocate for the American Federation of Government Employees Local 3607 representing professional and non-professional employees in EPA Region 8. I have also served as the President of Local 3607 in the past.

EPA's failure to regulate the injection of fluids for hydraulic fracturing of coal bed methane reservoirs appears to be improper under the Safe Drinking Water Act and may result in danger to public health and safety. I respectfully request that you investigate this matter and respond as you and other members of Congress deem appropriate.

Sincerely,

Weston Wilson

Enclosure: EPA Allows Hazardous Fluids to be Injected into Ground Water, A report on EPA's failure to protect America's ground water from the impacts of oil and gas production, Weston Wilson, October 7, 2004, 18 pages.

cc: Representative Bob Beauprez
Representative Joel Hefley
Representative Marilyn Musgrave
Representative Scott McInnis
Representative Thomas Tancredo
Representative Mark Udall
EPA Office of the Inspector General

EPA Allows Hazardous Fluids to be Injected into Ground Water

A report on EPA's failure to protect America's ground water
from the impacts of oil and gas production

A technical analysis by Weston Wilson, an employee of the U.S. Environmental Protection Agency

October 8, 2004

Abstract

EPA has established that: 1) coal bed methane hydraulic fracturing occurs within underground sources of drinking water, 2) hydraulic fracturing fluids contain toxic components that are not entirely removed during methane gas production, and 3) this fracturing process can create pathways which allow methane to migrate into high quality ground water. The industry's practice of hydraulically fracturing coal bed reservoirs could endanger underground sources of drinking water and render these aquifers unusable as a future drinking water supply. Therefore, the industry practice of hydraulic fracturing of coal beds should be investigated further by EPA and, if found harmful, or potentially harmful, to ground water and other resources, should be regulated by EPA throughout the United States.

Disclaimer

The views and opinions contained in this report are not those of EPA. I am solely responsible for all information contained in this report. I was not involved in either the preparation or review of EPA's report on the hydraulic fracturing of coal bed methane reservoirs.

I request the rights granted under the first amendment to the United States Constitution and assert protection under the Whistleblowers Protection Act should the Environmental Protection Agency retaliate against me for speaking to members of Congress or speaking to the press or speaking to the public about the matters contained herein.

Weston Wilson Oct. 8, 2004

Weston Wilson, October 8, 2004

A. Author's conclusions about EPA's failure to protect ground water

In June 2004, EPA's Office of Water in Washington, D.C., completed a study on the potential effects to underground sources of drinking water resulting from the industrial practice of hydraulically fracturing coal bed reservoirs to produce methane. EPA concluded this practice poses little or no threat to underground sources of drinking water and does not warrant additional site-specific investigations. As a result of this conclusion, EPA will not regulate this activity anywhere except in the State of Alabama where a federal court ordered that EPA must do so.

Despite EPA's conclusions that this practice poses little or no threat to underground sources of drinking water, EPA obtained a national agreement from three oil and gas industry service companies indicating that these companies would stop injecting hydraulic fracturing fluids containing diesel fuel into coal bed reservoirs with good quality water. EPA has not sought to restrict other entities or any of the other toxic components of the fracturing fluids.

Some formulations of the hydraulic fluids used to fracture coal bed reservoirs are considered proprietary information by the oil and gas industry service companies. Because this information has been kept confidential as proprietary information, the public does not have access to information to determine whether these materials could endanger underground sources of drinking water.

Coal bed hydraulic fracturing, a method used to produce natural gas, may introduce toxic materials such as acids, benzene, toluene, ethyl benzene, xylene, formaldehyde, polyacrylamides, chromates, and other toxic components into underground sources of drinking water. Because it 'fractures' coal beds, hydraulic fracturing can also create new pathways for methane migration into aquifers containing good quality ground water, and thus into privately-owned water wells and community water supplies.

Except in Alabama, neither EPA nor the States regulate the type or quantity of toxic fluids used to fracture coal beds to produce methane. The toxic components of these fracturing fluids are not reported to any regulatory authority or to the public.

B. Hydraulic fracturing of coal bed reservoirs improves natural gas production

Natural gas, or methane, is adsorbed within coal beds. Natural gas can be produced after overlying ground water has been pumped out reducing the fluid pressure that holds the natural gas in place. Hydraulic fracturing in coal beds is the process of pumping thickened fluids into a well at a rate that exceeds the capacity of the coal bed to accept them. A large capacity pump is used to increase the pressure of the injected fluid which results in cracks or fractures, allowing a path to move the injected fluids along these newly formed fractures. The hydraulic fluid often contains propping agents, usually silica sand particles, which hold the fractures open after the pressure is released. While hydraulic fracturing of oil and gas found in conventional geologic traps is well established, hydraulic fracturing of coal beds is relatively new.

According to the Gas Technology Institute, natural gas from coal beds produced approximately 1.3 trillion cubic feet of natural gas in 2000. The Department of Energy estimates that approximately six percent of the U.S. total natural gas production in 2000 was obtained from coal beds and predicts this percentage will increase in the future.[1]

Natural gas is produced from nine coal basins in the United States, from Alabama to Montana, and is being explored in Alaska. Oil and gas service companies inject fluids for hydraulic fracturing of coal beds in Colorado, New Mexico, Utah, Wyoming, Montana, West Virginia, Virginia, Kentucky, Arkansas, Oklahoma, and Alabama. Approximately seventy percent of the total U.S. coal bed methane production is derived from the San Juan Basin in Colorado and New Mexico.

Unlike natural gas developed from conventional oil and gas deposits, geologic formations which contain coal bed methane can be near the surface where ground water may used as a source of drinking water supplies. Conventional oil and gas occurs in geologic traps that are usually associated with deep (generally over 1000 feet deep) and typically highly saline ground water that is unsuitable for drinking water. Enhanced recovery techniques used to develop conventional natural gas and oil in deep geologic structural traps, including fracturing the rock

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[1] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, Appendix A, Department of Energy – Hydraulic Fracturing White Paper, EPA Drinking Water Protection Division, Final Report, June 2004, page App. A-1. http://www.epa.gov/safewater/uic/cbmstudy.html

to allow more oil and gas to flow, are thus less likely to risk damage to usable ground water supplies. Although the practice of hydraulic fracturing has been used in the recovery of conventional oil and gas since the 1950s, this practice has been applied for recovery of coal bed methane only since the mid-1990s. And only in the last few years has the industry begun the injection of fluids to conduct hydraulic fracturing in aquifers that supply, or could supply, community and individually-owned drinking water wells.

C. <u>EPA decisions are not consistent with the findings of its study nor have EPA decisions complied with the purposes of the SDWA</u>

In EPA's June 2004 final report and court-directed decisions, EPA has acknowledged the following.

* Hydraulic fracturing fluids are injected into underground sources of drinking water and these fluids contain substances that are toxic and carcinogenic. (EPA apparently takes the position that the composition of these fluids may be propriety information and EPA was unable to find complete chemical analyses of these hydraulic fracturing fluids in the literature.)

* The primary function of these wells is to produce methane from coal beds; therefore, and not to inject fluids underground. Therefore, in EPA's opinion, these wells are not subject to the regulatory provisions of the Safe Drinking Water Act. (A federal appeals court has rejected that position as inconsistent with the Safe Drinking Water Act.)

* There is no further need for EPA to investigate the practice of hydraulic fracturing in coal bed methane reservoirs. (But EPA recognizes there is a lack of field water quality data regarding the fate of the substances in the hydraulic fracturing fluids within these sources of drinking water.)

* In the San Juan Basin of Colorado following coal bed methane production, unwanted methane gas has migrated into underground sources of drinking water from unplugged oil and gas wells. (But EPA did not investigate whether pathways created by hydraulic fracturing may contribute to methane contamination or contamination associated with fracturing fluids in underground sources of drinking water.)

Further, EPA actions do not appear to be based on objective and impartial information.

* EPA relied upon an external peer review panel that supported EPA's findings and conclusions. (However, five of EPA's seven-member Peer Review Panel appear to have conflicts-of-interest.)

* EPA utilized a seven-member Peer Review Panel composed only of external experts. (EPA's Peer Review Panel members did not achieve the needed balance of interests by including EPA professional staff with knowledge and expertise on these matters. Further, EPA did not include its most experienced professional staff to participate and prepare EPA's study of the impacts of this industry practice.)

* EPA obtained a national agreement from three oil and gas service companies to cease the use of diesel fuel in hydraulic fracturing fluids in coal bed methane reservoirs. (However this agreement is voluntary and non-enforceable. EPA has no oversight of these companies to assure that diesel fuel is no longer used in hydraulic fracturing fluids in coal bed methane reservoirs.)

The following information addresses each of the above claims of improper conduct by EPA which may result in danger to public heath and safety. This information was obtained from publicly-available sources including Congress, EPA, Department of Energy, Occupational Safety and Health Administration, or from the scientific literature as noted.

1. <u>Hydraulic fracturing fluids may contain toxic components</u>

Hydraulic fracturing fluids consist of water, foamed liquids, thickening gels, and propping agents. Fracturing fluids used in the northern San Juan Basin, for example, include: 1) hydrochloric acid, 12% to 28% HCl with pH less than 1 to 3, 2) water mixed with hydrocarbon-based solvents such as diesel fuel, 3) gels containing guar-gum or a polymer such as polyacrylamide, and 4) cross-linked gels with 'breaker' chemicals.[2]

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[2] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA June. 2004, Attachment 1 – San Juan Basin, page A1-7.

In addition to diesel fuel, which contains benzene, toluene, ethyl benzene and xylene, fluids used in coal bed methane hydraulic fracturing may also contain acids, formaldehyde, polyacrylamides[3], chromates, and other potentially toxic or carcinogenic substances.[4] These compounds can reduce viscosity after fracturing so that the gels can be pumped back to the well after treatment, impart corrosion protection for metal casings in the well, reduce bacterial growth, and have other production benefits. Because thickening gels dissolve more readily in diesel fuel than in water, using diesel fuel increases the transport of the sand propping agent in the fracturing fluids. According to EPA's findings: "Many of the compounds listed in Table A1-1 are quite hazardous in their undiluted form. However, these compounds are substantially diluted prior to injection."

Oil and gas production wells, including all coalbed methane production wells in the San Juan Basin, are permitted by either the Colorado Oil and Gas Board or by the New Mexico Oil and Gas Board. Both agencies regulate the underground disposal of coal bed methane produced water as Class II wells under the SDWA. However, based on EPA's analysis of current regulations, "neither agency regulates the type or amount of fluids used for (coal bed methane hydraulic) fracturing."[5]

Oilfield service companies, including Halliburton, Schlumberger, and JB Services Company, supply the fracturing fluids used to fracture the coalbeds as part of their service contracts. Again, according to EPA's findings: "The chemical composition of many fracturing fluids used by these service companies may be proprietary, *and EPA was unable to find complete chemical analyses of any fracturing fluids in the literature.*"[6] (Emphasis added.)

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[3] Polyacrylamide may be contaminated with acrylamide, which is a toxic substance. Polyacrylamide may also degrade in the environment to acrylamide. EPA established a limit of 500 ppm acrylamide contamination in polyacrylamide products to be acceptable for use in water treatment systems. 40 C.F.R. 141.61 See also Smith, et.al. 1996, Environmental degradation of polyacrylamides, Toxicological Sciences 35(2):121-135 and Khan, et.al. 1999, Changes in thyroid gland morphology after acute acrylamide exposure. Toxicological Sciences 47(2):151-157.

[4] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA June, 2004, Attachment 1 - San Juan Basin, Table A1-1.

[5] Ibid. Attachment 1- San Juan Basin, page A1-7 which cites the Colorado State Oil and Gas Board Rules and Regulations 400-3, 2001; and New Mexico Energy, Minerals and Natural Resources Department, Oil Conservation Division Regulations, Title 19, Chapter 15, 2001.

[6] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA, June 2004, page A1-7.

2. EPA's legal position has been rejected by the only court that has considered this matter

The Safe Drinking Water Act (SDWA) is designed to protect underground sources of drinking water from contamination caused by underground injection of fluids. (See 42 U.S.C. Sections 300h to 300h-8.) The law requires EPA to promulgate regulations for states to administer these provisions of the law in order to protect underground sources of drinking water. According to EPA regulations an underground source of drinking water is an aquifer used for drinking water supply or one that is capable of being used in the future, because it contains less than 10,000 parts per million total dissolved solids and has sufficient water yield to serve as a drinking water supply.[7]

The SDWA provides the authority to EPA to regulate underground injection practices. In approving this Act, Congress directed that EPA should not prescribe unnecessary regulation on oil- and gas-related injection.

EPA determined in 2001 it would conduct a nationwide study to assess the potential of hydraulic fracturing of methane bearing coal beds to endanger underground sources of drinking water. Prior to 1997, EPA had not regulated hydraulic fracturing because it determined this process did not fall under the Underground Injection Control Program's authority under the SDWA.[8] EPA at that time believed that methane gas production wells that employed hydraulic fracturing need not be regulated pursuant to the SDWA because the principal function of these wells is methane gas production and not the underground injection of fluids.

In 1994, the Legal Environmental Assistance Foundation (LEAF) petitioned EPA to regulate this practice in Alabama under the SDWA. EPA denied LEAF's petition and LEAF litigated the matter. The Eleventh Circuit Court of Appeals ruled EPA's interpretation was inappropriate. The court stated: "[We] conclude that hydraulic fracturing activities constitute underground injection under Part C of the SDWA. Since EPA's contrary interpretation could not be squared with the plain language of the statute, we granted LEAF's petition and remanded for further proceedings." Further, the court stated that "... as LEAF correctly notes, wells used for the injection of hydraulic fracturing fluids fit squarely within the

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[7] 40 C.F.R. part 144.3. http://www.epa.gov/safewater/uic/classes.html

[8] Federal Register, Volume 66, Number 146, pages 39396-39397.

definition of Class II wells. Accordingly, they must be regulated as such."[9] In 1999, Alabama amended its Underground Injection Program to include the regulation of injection of fluids for coal bed reservoir hydraulic fracturing as Class II wells under the SDWA and EPA approved.[10] The court's 1997 decision held that the injection of fluids for hydraulic fracturing is underground injection and in 2001 the court decision held that methane production wells doing hydraulic fracturing were Class II wells. Class II wells under EPA's Underground Injection Control Program regulations include wells which inject fluids for enhanced recovery of oil or natural gas.[11]

The court ordered EPA to require hydraulic fracturing for coal bed methane production to be regulated in Alabama pursuant to the SDWA. EPA has not applied the court's reasoning and interpretation of the law in any other part of the nation, nor did EPA appeal the decision by the 11th Circuit Court. EPA's decision is contrary to the only reported court decision that considered this matter. EPA appears determined to confine the 11th Circuit Court decision to only within the jurisdiction of the 11th Circuit.[12]

In 2001, in response to the 11th Circuit Court's decision and based on concerns by citizens in several states who claimed they may be affected by coal bed methane production practices, EPA proposed a three-phase study design. EPA focused its study on the impacts of the toxic substances contained in fluids used to fracture coalbeds. EPA formed a Peer Review Panel of professional reviewers to evaluate its findings. EPA did not form a federal advisory panel of citizens and other interested parties as appropriate for significant national decisions pursuant to the Federal Advisory Committee Act.

3. <u>EPA should have conducted further investigation based on its findings</u>

EPA proposed a study to be conducted in three phases. In its first phase, EPA conducted a fact-finding effort based on the existing literature. The intent of phase one was to identify and assess the potential threat to underground

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[9] <u>Legal Environmental Assistance Foundation vs. United States Environmental Protection Agency</u>, United States Court of Appeals for the Eleventh Circuit, No. 00-10381, EPA No. 65-02889-Fed. Reg., December 21, 2001. http://www.epa.gov/safewater/uic/leaf2.pdf

[10] <u>Federal Register</u>, Volume 64, Number 204, October 22, 1999, pages 56986-56991. http://www.epa.gov/safewater/uic/alc2.html.

[11] 40 C.F.R. part 144.6(b). www.epa.gov/safewater/contaminants/dw_contamfs/acrylami.html

[12] The 11th Circuit Court of Appeals includes Alabama, Georgia, and Florida. Coal resources are not present in either Georgia or Florida.

sources of drinking water posed by injection of hydraulic fracturing fluids into coal bed reservoirs. In the second phase, EPA planned to conduct field investigations to obtain water quality data near wells that were hydraulically fractured within or near underground sources of drinking water to determine the extent of potential risks. If the second phase of study resulted in identifying potential risks to underground sources of drinking water, EPA planned to conduct a third phase. This third study phase would have considered and analyzed various regulatory mechanisms pursuant to the SDWA to control or minimize any potential risk that EPA had determined existed based on results obtained from the second phase of study.

In phase one EPA defined two mechanisms whereby hydraulic fracturing could potentially impact underground sources of drinking water: 1) direct injection or injection where there is already a hydraulic communication with an underground source of drinking water, and 2) creation of hydraulic connections with an adjacent underground source of drinking water through fracturing mechanisms.[13] EPA should have also investigated whether this practice resulted in unwanted migration of methane because EPA had received complaints from citizens regarding methane in drinking water wells.

In phase one, EPA also investigated citizen-reported incidents of water quality degradation potentially associated with these mechanisms. Since the hydraulic fracturing practice is not regulated by either EPA or the States, this meant that the data would have to be obtained from the industry itself in order to demonstrate water quality degradation. There was no such water quality data from industry monitoring programs available in the literature.

Based on the existing literature and field visits, EPA identified seven coal basins where the industry was injecting hydraulic fracturing fluids either into, or adjacent to, an underground source of drinking water. Table A presents a summary of the water quality conditions in coal bed methane production areas.

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[13] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA, June 2004, Appendix B, Quality Assurance Plan, page App. B-5.

Table A – U.S. coal basins where hydraulic fracturing may take place into, or adjacent to, an underground source of drinking water

Coal Basin	Location by State	Coal bed reservoir used, or adjacent to, drinking water supply	Water Quality total dissolved solids (ppm)
San Juan Basin, northern and eastern edge	Colorado	Yes	180 - 3015[14]
Black Warrior Basin – western edge of basin	Alabama	Yes	50 to less than 10,000[15]
Powder River Basin	Wyoming and Montana	Yes, but hydraulic fracturing is seldom utilized	850[16]
Central Appalachian Coal Basin	Virginia, West Virginia, and Kentucky	Yes	less than 1000[17]
Northern Appalachian Coal Basin	Pennsylvania, West Virginia, Ohio, Kentucky, and Maryland	Yes	2000-5000[18]
Western Interior Basin (Arkoma Basin)	Arkansas and Oklahoma	Yes	55-534[19]
Raton Basin	Colorado	Yes	1000-2500[20]
Sand Wash Basin	Colorado and Wyoming	No	less than 10,000[21]

[14] Ibid, at page A1-4. See Table A1-1. Hydraulic fracturing fluids contain acids, formaldehyde, chromates, polyacrylamides, and diesel which contain benzene, ethyl benzene, toluene, and xylene.

[15] Ibid. at page A2-3 through A2-5. Fracturing fluids contain water and gels and may contain chromates, formaldehyde, and polyacrylamides. See Table A2-1. According to service companies there, diesel fuel is no longer used in Alabama.

[16] Ibid. page A5-8, A5-9. Hydraulic fracturing is rarely used in the Powder River Basin because it would increase groundwater flow into the coal bed methane production wells.

[17] Ibid. page A6-4, A6-5.

[18] Ibid, at page A7-3.

[19] Ibid. at page A8-3 and A8-9. Hydraulic fracturing fluids contain acids, benzene, xylene, toluene, gasoline, diesel, solvents, bleach, and surfactants.

[20] Ibid. at page A9-3. Hydraulic fracturing fluids are typically gels and water with sand propping agents.

[21] Ibid. at page A10-3. There is limited development in this basin by one company using hydraulic fracturing fluids containing gels and water with sand propping agents.

EPA received several citizen reports of cloudy water and objectionable odors in their well water after a service company had conducted hydraulic fracturing services in their neighborhood. Based on the available literature and field data in the San Juan Basin, EPA attributed citizen-reported incidents to causes other than hydraulic fracturing, including the possibility of methane migration associated with nearby abandoned unplugged oil and gas wells.

Most citizens lack the resources needed to obtain reliable water quality data for trace concentrations of hydrocarbons such as benzene which may be associated with hydraulic fracturing fluids. Citizens are also unlikely to have sampled their water supply before and after a service company conducts hydraulic fracturing in order to establish baseline conditions and causality. The industry has not reported water quality data in nearby water wells before or after hydraulic fracturing services in the existing literature.

EPA should have initiated phase two of its study because it concluded that toxic and carcinogenic substances are injected directly into underground sources of drinking water by hydraulic fracturing practices. Conducting phase two of its study would have been consistent with EPA's scientifically-valid principle established in its phase one study design. Therefore, based upon EPA's own findings, EPA should begin phase two of its intended study and conduct site-specific field analysis and independent water quality data investigations wherever hydraulic fracturing is being conducted in underground sources of drinking water.

4. EPA did not investigate pathways for unwanted methane migration

EPA's report acknowledges that methane has migrated into domestic wells used to supply drinking water associated with coal bed methane production, specifically in the San Juan Basin in Colorado. Methane is a highly flammable and asphyxiating gas. In confined spaces, methane at sufficient concentrations can induce unsafe conditions due to the risk of combustion or simple asphyxiation. Methane can saturate soils resulting in reduced plant growth, even killing plants and trees by depleting oxygen supply to plant roots. In the San Juan Basin of Colorado, the U.S. Department of the Interior's Bureau of Land Management provided a history of gas seeps and methane contamination of drinking water wells following citizen reports of methane in wells.[22] The composition of the gas in samples from shallow, private drinking water well was

[22] Ibid. page 6-6. See also, Bureau of Land Management, Draft Environmental Impact Statement, Southern Ute Gas Development, 1999.

analyzed to confirm the well owners' observations. The data obtained showed that the methane in approximately half of the samples appeared to have originated in the Fruitland Formation coal beds, the source of coal bed methane in the basin.[23] Methane migrated into soils near the Fruitland Formation outcrop in the northern edge of the basin resulting in dead grasses and trees. Amoco operates coal bed methane production in the San Juan Basin and decided to buy three ranches after La Plata county officials tested indoor air and found extremely high levels of methane.[24]

The1999 Bureau of Land Management report regarding the San Juan Basin attributed the following possible pathways for methane to move from a deep source to a shallow aquifer: 1) natural fractures, 2) hydraulically-induced fractures, 3) disposal of produced water from coal bed methane wells, 4) poorly constructed, sealed, or cemented conventional gas wells, 5) coal bed methane wells, 6) shallow drinking water wells, and 7) cathodic protection wells installed to protect oil and gas pipelines from corrosion.[25]

EPA's study failed to investigate that methane could travel along the pathways created by the hydraulic fracturing process. This is an especially important contamination pathway that is more likely to result from hydraulic fracturing in shallow, near-surface, coal beds. Hydraulically-induced fractures break at right angles to the least stress. In deep formations, generally greater than 1000 feet, fractures are more likely to be break vertically due to the intense overburden pressure which restrains fracturing horizontally. In shallow hydraulic fracturing locations, generally less than 1000 feet, fracturing can occur horizontally at significant distances from the well.[26] Shallow locations are most likely to include underground sources of drinking water. EPA made no attempt in its study to investigate the movement of unwanted methane as a result of hydraulic fracturing inducing such new pathways.

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[23] Ibid. page 6-7.
[24] Ibid. page 6-3. Methane threshold limit values are established by the Occupation Safety and Health Administration. See http://www.osha.gov/dts/chemicalsampling/data/CH_250700.html.
[25] Ibid. page 6-8. See also, Bureau of Land Management, Draft Environmental Impact Statement, Southern Ute Gas Development, 1999.
[26] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA, June 2004, Appendix A, Department of Energy - Hydraulic Fracturing White Paper, pages A6-A11.

5. Five members of EPA's Peer Review Team appear to have conflicts-of-interest

EPA's peer review process uses one of two forms. The review team may consist primarily of relevant experts from within EPA who have no other involvement with respect to the work product that is to be evaluated, known as the "internal peer review" process. A peer review team may also consist primarily of independent experts from outside EPA, known as the "external peer review" process. Peer review teams may also be formed with representatives of both internal and external experts.[27] For this study, EPA selected an external peer review team that did not include any EPA expert.

According to EPA's policy, external peer reviewers should be chosen to ensure an independent and objective evaluation. The affiliations of peer reviewers should be identified on the public record, so as to avoid undercutting the credibility of the peer-review process by conflicts-of-interest. EPA's policy states that peer reviewers should be free of real or perceived conflicts-of-interest or there should be a balancing of interests among peer reviewers. EPA's policy states that the matter of obtaining a fair and credible peer review, as well as maintaining the credibility of the Agency and the Agency's scientific products, is of paramount importance. EPA's managers are encouraged to assure peer reviewers do not have a legal or perceived conflict of interest that creates the appearance that the peer reviewer lacks impartiality or objectivity. According to EPA's policies, conflicts-of-interest could occur if reviewers are affected by their private interests or when the reviewers and their associates would derive economic or other benefit from incorporation of their point of view in an Agency product.[28]

Five of the seven members of EPA's Peer Review Panel formed to evaluate the impacts of hydraulic fracturing of coalbed methane reservoirs appear to have a conflict of interest. The Peer Review Panel includes three individuals employed by the oil and gas industry. These individuals may benefit from incorporation of their point of view if EPA and the States do not regulate the practice of hydraulic fracturing. Peer Review Team members with a possible financial conflict of

[27] Peer Review and Peer Involvement at the U.S. Environmental Protection Agency, 1 EPA/600/9-91/050, March 1992.

[28] Science Policy Handbook, Office of Science Policy, U.S. Environmental Protection Agency, Office of Research and Development, December 2000, EPA 100-B-00-001, Sections 3.4.5-6. http://epa.gov/osa/spc/htm/prhandbk.pdf

interest include Ian Palmer, a petroleum engineer with BP Amoco, Buddy McDaniel, a technical advisor for Halliburton Energy Services, Inc, and David Hill, an engineer with the Gas Technology Institute. Two other members have an appearance of potential conflict of interest as a result of previous employment in the oil and gas industry including Morris Bell, an engineer with the Colorado Oil and Gas Conservation Commission who was formerly an employee of BP Amoco, and Jon Olson, an assistant professor at the University of Texas, formerly employed by Mobil Exploration. The other peer review panel members are Peter E. Clark, an associate professor at the University of Alabama, and Norm Warpinski, from Sandia Laboratories.

6. EPA did not include in its Peer Review Panel any EPA expert nor did EPA include its most experienced professional staff to participate in its study of hydraulic fracturing of coal bed methane reservoirs

EPA did not include on its Peer Review Team any qualified, experienced professional employed by EPA that is knowledgeable with: 1) the industries' hydraulic fracturing practices in each coal basin, 2) human and animal toxicological effects with regard to the toxic and carcinogenic components of the injected fluids, or 3) groundwater flow in these coal basins regarding the fate and transport of these fluids in these specific underground conditions. Had EPA included on its Peer Review Panel key experienced EPA staff, not directly involved in the preparation of EPA's study, it may have provided a balancing of interests among peer reviewers to achieve the goals cited in EPA's science policy.

Utilizing a Peer Review Panel composed largely of the members of the regulated industry with real or perceived conflicts-of-interest and failing to assign EPA's most experienced and independent professionals has contributed to EPA producing a decision that lacks impartiality and objectivity.

Further, EPA did not include its most experienced professional staff to prepare and review EPA's study of the impacts of this industry practice. EPA should have included as part of its team of experts preparing this study experienced professional staff including toxicologists and hydrogeologists knowledgeable about the fate and transport of trace substances associated with the ground water flow conditions unique to each coal basin.

7. Three service companies have agreed not to inject diesel fuel in hydraulic fluids used for hydraulic fracturing of coal bed methane reservoirs

In the study, EPA acknowledges that potentially hazardous substances may be introduced into underground sources of drinking water when fracturing fluids are injected into coal bed reservoirs. In particular, EPA notes that diesel fuel, if used in hydraulic fracturing fluids, could introduce toxic substances because diesel fuel contains benzene, toluene, ethyl benzene, and xylene which are toxic at low concentrations.[29] EPA has established the maximum concentration limit for benzene in drinking water at five parts per billion. Benzene is a carcinogen and therefore harmful to those who drink it.[30] EPA established goal for benzene concentrations in drinking water is not to exceed the level of analytical detection which is less than one part per billion.[31]

Based on its June 2004 study, EPA concludes that the practice of hydraulic fracturing in coal bed reservoirs is safe, poses little of no threat to underground sources of drinking water, and does not need to be further studied or regulated. EPA supports this conclusion based on an action that EPA believes will reduce the risks of endangerment to underground sources of drinking associated with injecting diesel fuel into coal bed methane reservoirs. EPA obtained an agreement from three oil and gas industry service companies to *voluntarily* eliminate diesel fuel injection into underground sources of drinking water for coalbed methane production.[32]

These companies did not agree with EPA's concerns. The agreement states: "While the companies do not necessarily agree that hydraulic fracturing fluids using diesel fuel endanger USDWs (underground sources of drinking water) when they are injected into CBM (coal bed methane) production wells, the companies are prepared to enter into this agreement in response to EPA's concerns and to reduce potential risks to the environment."[33]

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[29] Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coaled Methane Reservoirs, EPA, June 2004, at page ES-16.

[30] 40 C.F.R. 141.61 http://www.epa.gov/safewater/contaminants/dw_contamfs/benzene.html

[31] 40 C.F.R. 141.50

[32] Memorandum of Agreement Between the United States Environmental Protection Agency and BJ Services Company, Halliburton Energy Services, Inc. and Schlumberger Technology Corporations, Elimination of Diesel Fuel in Hydraulic Fracturing Fluids Injected into Underground Sources of Drinking Water During Hydraulic Fracturing of Coalbed Methane Wells, signed by G. Tracy Mehan, III; EPA Office of Water and representatives of the above companies, December 12, 2003.

[33] See Memorandum of Agreement, ibid. page 2.

Because the agreement is voluntary, the public and regulators cannot determine whether these service companies will comply with the conditions established in the agreement.

The agreement does not appear to be enforceable by EPA or any party and EPA has no oversight to assure that the conditions established in the agreement are achieved. The agreement states: "Any company or EPA may terminate its participation in this MOA (memorandum of agreement) by providing written notice to the other signatories."[34]

This agreement also does not refer to any other toxic or carcinogenic substance that could be contained in hydraulic fracturing such as acids, formaldehyde, polyacrylamides, chromium, and other substances. As some hydraulic fracturing fluids remain proprietary, it is not known if other toxic substances are contained in hydraulic fracturing fluids.

This agreement does not refer to the potential of hydraulic fracturing creating new pathways for methane migration to endanger underground sources of drinking water.

This agreement does not apply to any other service company or any owner of a well that may inject diesel fuel to hydraulic fracturing coal beds for methane recovery.

D. EPA should conduct additional analysis and consider regulatory options

Congress is considering exempting the practice of hydraulic fracturing by the oil and gas industry perhaps before EPA can conduct further investigations. The public should be wary of exempting this practice from regulatory oversight by EPA. EPA should correct is faulty analysis. This can be accomplished if EPA reverses its decisions and begins anew its proposed three-phase study of the impacts of injection of fluids for hydraulic fracturing of coal bed reservoirs, provided it is conducted, this time, in compliance with EPA's science policies.

[34] Memorandum of Agreement, ibid. page 5.

1. The oil and gas industry is now seeking to exempt the practice of hydraulic fracturing from the requirements of the SDWA

Congress has a legislative amendment under consideration that would exempt the practice of hydraulic fracturing from compliance with the SDWA with support based, in part, on EPA's flawed analysis. Section 327 of the proposed Energy Bill (H.R. 6)[35] would amend sections 1421(d) of the Safe Drinking Water Act (42 U.S.C. 300h(d)) to exclude the underground injection of fluids or propping agents pursuant to hydraulic fracturing operations related to oil and gas production activities.

This legislative change, if approved by Congress, would exempt this practice for both coal bed methane production and for conventional oil and gas production. EPA has not applied its authority under the SDWA to investigate the risks of endangerment to underground sources of drinking water that might result from hydraulic fracturing in underground sources of drinking water associated with conventional oil and gas production.

The oil and gas service companies that are parties to the Memorandum of Agreement could withdraw from the conditions set forth in the agreement as soon as legislation is in place with little or no recourse by EPA or affected citizens. These service companies could recommence the practice of injecting fluids containing diesel fuel into coal bed methane reservoirs which could risk public health or the safety of the environment.

2. The public should be wary of exempting this practice from compliance with the Safe Drinking Water Act

The reasons that exemption of this industry practice from the regulatory provisions of the SDWA may not be warranted at this time include: 1) the risks of endangering underground sources of drinking water from hydraulic fracturing practices are poorly understood due to a lack of field monitoring data; 2) these risks deserve extensive additional study; 3) the injection practices introduce toxic and carcinogenic materials that are not likely to be fully recovered during production; 4) the content of these hydraulic fracturing fluids is unknown; 5) the majority of EPA's external peer review panel, whose review supports the decision, appear to have conflicts-of-interest, and; 6) the only national precedent

[35] H.R 6 PP. http://thomas.loc.gov/cgi-bin/query/D?c108:5:./temp/~c108BCiRdc::

established to control impacts to underground sources of drinking water from hydraulic fracturing is an unenforceable voluntary agreement.

3. Recommendations to EPA to correct its faulty analysis

a) EPA should revise and amend EPA's June 2004 study conclusions. EPA should begin anew its three-phase study of the risks to underground sources of drinking water from the hydraulic fracturing of coal bed methane reservoirs. This revised study should also investigate migration of unwanted methane associated with the practice of hydraulic fracturing in coal bed methane reservoirs.

b) EPA should form a federal advisory panel including interested citizens to provide oversight of EPA's study efforts consistent with the Federal Advisory Committee Act.

c) EPA should form a new Peer Review Panel and include a balance of interests among peer reviewers by assigning internal and external peer reviewers. This panel must be comprised to avoid reviewers with real or perceived conflicts-of-interest.

d) If the data and analytical results of phase two indicate that an underground source of drinking has or may become endangered as a result of hydraulic fracturing in coal bed reservoirs, EPA should conduct phase three of its study to investigate regulatory program options consistent with the Safe Drinking Water Act and the Toxic Substances Control Act. This effort should identify the benefits and costs of Alabama's application of that state's SDWA Underground Injection Control Program which regulates hydraulic fracturing in coal bed methane reservoirs.

Professional qualifications of the author

Wilson received a Bachelors of Science degree in Geological Engineering in 1969 and a Masters of Science degree in Water Resources Administration in 1973 from the University of Arizona. He has received numerous honors and awards for his professional accomplishments at the EPA during his 30-year career with the federal government. In 2003, Wilson received the "Four C's Award" from Kathleen Clark, Director of the Bureau of Land Management, for his analysis of the surface water quality impacts associated with coal bed methane development in Montana and Wyoming. The 'Four C's Award' is awarded to federal employees for their "consultation, cooperation, communication, (for) conservation."