February 2013 I www.epa.gov/hfstudy

United States
Environmental Protection
Agency

Summary of Technical Roundtables on EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

November 14–16, 2012

Disclaimer

This report was prepared by EPA with assistance from Eastern Research Group, Inc., an EPA contractor, as a general record of discussions during the technical roundtables on EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, which took place on November 14–16, 2012. The report captures the main points of opening presentations and facilitated discussions on the technical theme of each roundtable. The report is not a complete record of all details discussed. Except as noted, none of the statements in the report represent analyses or positions of EPA. All statements and opinions expressed represent individual views of the invited participants and there was no attempt to reach consensus on any of the technical issues being discussed.

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Contents

Section 1. Introduction/Overview

On November 14–16, 2012, the U.S. Environmental Protection Agency (EPA) conducted a series of five technical roundtables focused on each stage of the water cycle, as defined in the study plan for EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. In this study, each stage of the cycle is associated with a primary research question:

- **Water acquisition:** What are the possible impacts of large volume water withdrawals from ground and surface waters on drinking water resources?
- **Chemical mixing:** What are the possible impacts of hydraulic fracturing fluid surface spills on or near well pads 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 flowback and produced water (collectively referred to as "hydraulic fracturing wastewater") surface spills on or near well pads on drinking water resources?
- **Wastewater treatment and waste disposal:** What are the possible impacts of inadequate treatment of hydraulic fracturing wastewater on drinking water resources?

Based on feedback from the November 2012 roundtables, EPA will host in-depth technical workshops to address specific topics in greater detail. EPA believes a transparent, research-driven approach with significant stakeholder involvement can address questions about hydraulic fracturing.

Robert Sussman, Senior Policy Council to the Administrator, provided opening remarks. Mr. Sussman stated that the Administration is supportive of growing our domestic natural gas resources, and that resources must be developed in a safe and responsible manner. EPA is working to ensure that the Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources meets the highest scientific standards. EPA is committed to using the best available science, independent sources of information, and a transparent, peer-reviewed process that will ensure the validity and accuracy of results. To that end, EPA is soliciting input from stakeholders throughout the process to obtain timely and constructive feedback on projects undertaken as part of the study. The report of results and research products supporting the report of results will undergo meaningful and timely peer review, taking into account the study's designation as a Highly Influential Scientific Assessment (HISA).

Mr. Sussman noted that EPA's goals for these roundtables were to discuss key aspects of this complex study and develop a list of potential topics for future technical workshops. EPA will use the feedback and information shared with EPA at the technical roundtable meetings to:

- Inform interpretation of the research being conducting as part of the current study.
- Identify any additional data and studies EPA can use to inform its report (with emphasis on data having well-documented quality assurance/quality control and peer-reviewed studies).
- Identify additional possible future research (by EPA or others).
- Identify possible topics for follow-on technical workshops.

EPA understands that unconventional oil and gas production is a dynamic industry and wants to stay informed on changes in industry practices and technologies so that the report of results reflects an up-to-date picture of hydraulic fracturing operations.

Ramona Trovato, Associate Assistant Administrator, EPA Office of Research and Development (ORD), provided a summary of the timeline for the Hydraulic Fracturing Study:

- In March 2010, at the request of the U.S. Congress, EPA announced plans to develop a comprehensive research study on the potential impact of hydraulic fracturing on drinking water resources. The final study plan was published in November 2011.
- The research status will be presented at these roundtable discussions. Following these roundtable meetings, EPA will hold a series of technical workshops to discuss selected technical issues in greater depth. These technical workshops will begin in February 2013 and continue as needed.
- EPA will release a progress report in December 2012.[1] While the progress report will not include findings or conclusions, it will provide the public with an update on study activities and future work.
- EPA expects to brief the Science Advisory Board (SAB) Ad-Hoc Hydraulic Fracturing Advisory Panel in spring 2013 on the 2012 progress report. Public comment will be solicited as part of the SAB's meetings regarding the report.
- Upon completion of the last technical workshop, EPA will reconvene the roundtables to review the work addressed in the technical workshop series.
- To improve public understanding of the study, EPA will increase the frequency of webinars. For instance, after the initial set of roundtables and each technical workshop, EPA will host a webinar to report out to the public.
- EPA expects to release the draft report of results in December 2014 for peer review.

Ms. Trovato noted that a copy of the November 9, 2012, *Federal Register* notice (77 FR 67361) is included in the folders that meeting participants received. EPA invites the public to submit data and scientific literature to inform EPA's research study on the potential impacts of hydraulic fracturing on drinking water resources. EPA is conducting a thorough literature search, but there might be studies or other primary technical sources that are not available in the open literature. EPA would appreciate input from the public to help inform current and future research and ensure a robust record of scientific

[1] Released December 21, 2012; available at http://epa.gov/hfstudy/

information. Consistent with our commitment to using the highest-quality information, EPA prefers studies that have been peer-reviewed. Interested persons may provide scientific analyses, studies and other pertinent scientific information. EPA will consider all submissions but will give preference to data with documented quality assurance and quality control information and peer-reviewed literature sources. EPA will accept data and literature in response to this request until April 30, 2013.

Sections 2 through 6 of this report summarize the study overviews presented at the roundtables and the discussions that followed, including discussion of potential topics for future technical workshops. The report summarizes suggestions and statements contributed by individual participants, grouped by topic. The statements reflect the views of individual participants, and do not reflect the view of a majority or consensus of participants, nor of EPA.

Materials from the 2012 technical roundtables, including agendas, attendee lists, participant bios, and presentation materials, are available at http://epa.gov/hfstudy/techwork13.html.

Section 2. Water Acquisition Roundtable

2.1 Study overview

Dr. Jennifer Orme-Zavaleta, Director of EPA's National Exposure Research Laboratory, described EPA's approach and progress in studying water acquisition. She presented three research questions:

1. How much water is used in hydraulic fracturing operations, and what are the sources of this water?
2. How might water withdrawals affect short- and long-term water availability in an area with hydraulic fracturing activity?
3. What are the possible impacts of water withdrawals for hydraulic fracturing operations on local water quality?

The data sources EPA is using to answer these questions include literature review, analysis of service company data, well file review, analysis of data from FracFocus (the national hydraulic fracturing chemical registry) and water availability modeling.

Dr. Orme-Zavaleta described EPA's water availability modeling approach, which is designed to evaluate possible impacts of large-volume water withdrawals for hydraulic fracturing on water availability in representative basins under realistic future scenarios. She discussed research progress in water availability modeling for the two study watersheds: the Upper Colorado River Basin and the Susquehanna River Basin.

2.2 Discussion

Water withdrawal impacts

Participants discussed a range of issues related to water withdrawal impacts. Individual participants raised the need to differentiate between the impacts of hydraulic fracturing and other impacts, impacts to small headwater areas and streams, the potential for water withdrawals to change aquifer flow and draw pollution into an aquifer, and unexpected water losses from interbasin water transfer. One participant remarked that seasonal impacts to ground water can be greater than hydraulic fracturing impacts. Several participants stated that sufficient data are not always available to provide a good idea of how much water can be withdrawn. One participant noted that the Susquehanna River Basin Commission has detailed data on water withdrawals. The importance of in-stream flow for aquatic life was also noted.

Impacts of hydraulic fracturing on public water supply systems

Participants discussed both positive and negative impacts of hydraulic fracturing on public water systems (PWSs). For example, a participant suggested that payment to PWSs for water use in hydraulic fracturing can allow for investment in infrastructure or other long-term needs, and could particularly help small municipalities improve their systems. It was also stated, however, that small rural water systems – which typically draw from shallow ground water – are the first to lose their water when drawdown occurs from supplying hydraulic fracturing operations. A participant noted that, while municipalities in some areas must meet requirements to allow their water to be used for hydraulic fracturing, such requirements do not exist in all locations. It was suggested that systems need drought contingency plans in case financial enticements lead municipalities to sell water they cannot spare.

Water use

Participants discussed water use for hydraulic fracturing in relation to other uses. A participant stated that oil and gas development constitutes a very small percentage of water use; agricultural and public water supplies are a huge percentage of water use in areas where hydraulic fracturing is occurring. One participant noted that the water required for hydraulic fracturing can often be met by available water supply. Another participant stated that water use should be considered in comparison to the length of the wells fractured on a linear foot basis, because wells with laterals (horizontal wells) tend to use less water per linear foot than vertical wells. The importance of identifying the tipping points was raised. A participant stated that many withdrawals are on small drainage areas, so withdrawal due to fracturing can constitute a large percentage of water use in those areas. It was noted that hydraulic fracturing is a consumptive use, while other water uses are not. It was also stated that industry should not stop looking for other water sources (outside of drinking water sources) just because it views itself as a small water user. A participant pointed to seasonal variations, in addition to long-term trends, as important considerations.

Water availability for hydraulic fracturing operations

Topics raised regarding water availability for hydraulic fracturing included working collaboratively with farmers and ranchers, encouraging use of more abundant surface waters (e.g., in Louisiana), and using water in springtime (high stream flow) to decrease impacts. In addition, some participants raised the topic of using time-limited water supply wells and drilling multiple wells on a pad to save resources.

Participants also discussed potential sources of water for hydraulic fracturing operations other than freshwater. A participant stated that some in industry would like to move away from using freshwater rather than just studying the impacts, to both increase corporate stewardship and decrease corporate risk. Other sources mentioned included glacial valleys (though baseflow can be impacted downstream), brine aquifers, highly treated wastewater discharges and water collected from abandoned mines. A participant also stated that more saline aquifers could be used for fracturing; however, not much work has been done to evaluate their use and availability.

Lifecycle analysis of recycling

Participants addressed recycling of flowback waters and lifecycle analysis of recycling. A participant said that many factors go into how companies manage water; these need to be evaluated on a case-by-case basis. A participant said that data from the Ohio River Basin in Pennsylvania show that about 2 percent of hydraulic fracturing water is being recycled. A participant stated that lifecycle analysis can determine in a holistic manner the utility of recycling. Another participant stated that recycling is not necessarily a "green" technology (due to impacts associated with increased truck traffic, the use of more additives and increased greenhouse gas emissions from recycling practices), and recommended that a different term be used. It was noted that air emissions, risks, regulatory structure, use of chemical additives, community impacts, energy use and issues with storing flowback waters for reuse all need to be considered.

Suggestions regarding modeling of potential impacts of water acquisition

- Consider water capture and delivery mechanisms.
- Consider ground water and surface water separately in the model.
- Consider U.S. Geological Survey data in calibrating the model for current locations.
- Consider both deep and shallow ground water in the model.
- Determine the reliability of the data being used and use the best available input data.
- Perform uncertainty and sensitivity analyses.
- In modeling, focus on dry cycles rather than wet cycles.
- Look at different scales for modeling in addition to the two counties being studied.
- Drill down to local issues (though regional models are important). It is impossible to have a tailored model for every system, but the most important parameters should be identified so that small localities can be prepared if impacts occur.
- Consider factors such as water rights issues and state regulations.
- Include boundary conditions (maximum withdrawal limits) that reflect regulatory requirements and best management practices.
- Consider impacts of methane on streams from the discharge of produced water from coalbed methane operations.

Additional topics for consideration

Participants raised several additional topics for consideration. Some participants suggested that the Ogallala, Fox Hills, Eagle Ford or Chicot aquifers be considered for ground water modeling and that U.S. Forest Service data be used for mapping ground-water-dependent ecosystems. One participant recommended looking at underground injection control (UIC) class II wells to meet some of the needs of hydraulic fracturing.

2.3 Potential topics for future technical workshops

- The underlying assumptions of the models and how they are evaluated and reviewed.
- All types of water use in addition to hydraulic fracturing, and regulatory/other programs in each basin, to better understand the impact of hydraulic fracturing in a particular area.
- Non-modeling issues, including:
    - What factors may be associated with short- and long-term impacts on drinking water supplies but may not be included in the model, such as where, when, how, how much and for how long is water being withdrawn?
    - Where is the water coming from and what types of water are being used?
    - What regulatory structures or contracts are in effect that impact what companies can do? (Note that this is beyond the scope of this research study.)

Section 3. Chemical Mixing Roundtable

3.1 Study overview

Dr. John Vandenberg, EPA's Human Health Risk Assessment National Program Director, gave a presentation about chemical mixing. He presented four research questions:

1. What are the identities and volumes of chemicals used in hydraulic fracturing fluids, and how might this composition vary at a given site and across the country?
2. What are the chemical, physical and toxicological properties of hydraulic fracturing chemical additives?
3. What is currently known about the frequency, severity and causes of spills of hydraulic fracturing fluids and additives?
4. If spills occur, how might hydraulic fracturing chemical additives contaminate drinking water resources?

EPA's data sources for answering these research questions include literature review, service company analysis, spills database analysis, well file review and FracFocus analysis.

Dr. Vandenberg described EPA's progress in assessing the toxicity of chemicals used in hydraulic fracturing and developing analytical methods in detail:

- **Toxicity assessment.** EPA is gathering information about toxicity associated with chemicals found in hydraulic fracturing fluids and wastewater to support future risk screening and assessments. EPA has identified 1,100 unique chemical substances and is identifying toxicity reference values. Where chemical structures are available, EPA plans to use Quantitative Structure-Activity Relationship (QSAR) modeling to predict the physical, chemical and potential toxicity of chemicals without available information in these areas.
- **Analytical methods development.** EPA is working to improve selected chemical methods so that they provide necessary detection and quantification limits in complex matrices. To select chemicals for methods development, EPA considered factors such as frequency of occurrence, mobility in the environment, and availability of instrumentation/detection systems. For selected analytes, EPA is assessing and modifying existing methods, where available. As part of the method modifications, EPA is sending samples to multiple labs for analysis to assess the performance of the modified method in complex matrices, and validating the method. EPA is currently modifying analytical methods for the following groups of compounds: glycols and related compounds, acrylamide, ethoxylated alcohols, disinfection byproducts, radionuclides and a few key elements (barium, strontium, boron, sodium, potassium, radium, uranium and thorium).

3.2 Discussion

Scope of the study

Several participants asked questions related to the scope of the study. EPA responded that it is looking at the potential impacts on drinking water resources from hydraulic fracturing as currently practiced.

EPA is currently examining what chemicals are or have been used in hydraulic fracturing and may be available to enter drinking water resources. It is looking at what might get into drinking water resources (surface water and ground water), and what disinfection byproducts may form when public water supplies treat water from sources downstream of discharges of hydraulic fracturing wastewater. EPA noted that it is pulling together available information regarding the chemical, physical and toxicological characteristics of chemicals known to have been used in hydraulic fracturing fluids or found in hydraulic fracturing wastewaters. EPA is not currently assessing the extent to which chemical and physical parameters might change in different extreme subsurface environments.

EPA noted that, while it is evaluating whether or not hydraulic fracturing impacts drinking water resources (and, if so, what the driving factors may be), it is not currently undertaking a risk assessment. The work EPA is doing now is the background work that could eventually support a risk assessment by any interested party. EPA first needs to understand whether hydraulic fracturing impact drinking water resources.

A participant stated that drilling through freshwater zones is one of the greatest concerns with hydraulic fracturing and that the effects are from drilling fluids, not hydraulic fracturing fluids. Drilling fluids (which may contain some of the same chemicals used in hydraulic fracturing fluids) are not being studied as part of EPA's current study.

List of chemicals known to have been used in hydraulic fracturing or found in hydraulic fracturing wastewater

EPA compiled information on chemicals reportedly used in hydraulic fracturing fluids or found in hydraulic fracturing wastewater. Sources of information included federal and state government documents, industry-provided data, and other reliable sources based on the availability of clear scientific methodology and verifiable original sources. This includes information provided by nine hydraulic fracturing service companies, nine oil and gas operators, and FracFocus. Many of the chemicals provided by the nine hydraulic fracturing service companies were claimed as confidential business information, and EPA has worked with these companies to publicly release many of these chemicals in the aggregated lists. EPA does not have precise names for many chemicals, and cannot rule out the possibility that other chemicals have been or are being used that EPA does not know about.

Analytical methods

Depending on the chemical, EPA is developing analytical methods specific to different media. EPA is looking at ground water, wastewater and flowback matrices, all of which vary by chemical. Validation of the analytical methods for glycols in drinking water matrices has begun, and has been tested by three EPA laboratories. The methods, which are based on two existing methods (SW-846 Method 8321 and ASTM D7731-11), are now scheduled to be tested by laboratories outside of EPA that have appropriate equipment.

Regarding the selection of compounds for which to develop analytical methods, EPA noted that there is a unique issue within each chemical group. For example, sometimes there are no standard methods available, such as for the ethoxylated alcohols; sometimes the standard methods are not sensitive enough or do not cover the complete suite of the compounds of concern, such as for the glycols; and sometimes matrix interferences, such as high salt contents, result in data of lesser or questionable quality, such as seen for the acrylamides, disinfection byproducts, metals and radioactivity/radionuclides (e.g., gross alpha and beta).

A participant stated that recycled water makes matrices more complicated, and asked if EPA will address degradation products. EPA agreed that recycling provides another matrix to consider. Parent compounds are the first priority; EPA did not start with degradation compounds, in part because addressing them can be complex and time consuming.

Chemical choice and "green" chemicals

The roundtable addressed the question of "green" chemical trends and use. A participant recommended that EPA consider the fact that chemical use during hydraulic fracturing changes over the life of the play. A participant noted that companies have specific purposes for adding certain chemicals (e.g., to produce relatively more product hydrocarbons than waste materials). A participant stated the view that these chemicals are being used safely and there are no unnecessary risks to the public; companies consider the frequency of use, severity and toxicity when deciding to use a chemical. A participant stated that sometimes a company believes that adding a chemical has a lower overall risk than not adding a chemical, when viewed over a broader spectrum of activities associated with producing the hydrocarbon resource (e.g., use of a biocide may later curtail the amount of hydrogen sulfide produced). It was also stated that identifying and using non-toxic chemicals could be helpful and minimize pollution. EPA noted that it does not have data for trends in use of chemicals, including chemicals described by the industry as "green," but would like to have this information. A participant stated that FracFocus might give trends over time if researchers look at the dates of data and identify trends by sorting similar locations and geologies.

Regarding ranking of chemicals, EPA noted that it would appreciate receiving information on any chemical ranking systems used by the oil and gas industry. A participant asked whether EPA can develop recommendations for manageable concentrations and volumes of chemicals. EPA stated that the U.S. Department of Energy (DOE) might be able to support research regarding what chemicals and/or chemical combinations might improve the hydraulic fracturing process. Several participants offered additional suggestions for EPA's role, including facilitation of conversations about alternative chemicals that different companies can use and standardization of the definition of "green" chemicals (similar to the National Sanitation Foundation's certification of products).

Spill data

EPA is looking at state databases and the National Response Center databases, which record incidents as they happen. The databases generally use reportable quantities as cutoffs for reporting requirements. Quantities of spilled material may not be included in some databases. EPA is not estimating contamination from spills by conducting subsurface or predictive modeling of fate and transport of spilled constituents as part of the current study. EPA noted that much work on the fate and transport of spilled chemical has already been completed and can be found in the scientific literature.

Spill prevention procedures were also discussed. EPA noted that certain industrial spill prevention and response practices are the same across industries; EPA tried to focus this study on situations specific to hydraulic fracturing.

Indicator and tracer compounds

Indicators are chemicals known to be present in hydraulic fracturing fluids or wastewater, while tracers are added to show the movement of hydraulic fracturing fluids or wastewaters. EPA asked roundtable participants to help identify and assess indicator and tracer compounds, as EPA would like to evaluate how they are used and for what purposes, A participant suggested that total dissolved solids (TDS) are easy to sample and reliable because produced water has high salt content. A participant noted that the group was discussing analytical methods and interferences, but it was necessary to keep in mind that indicator compounds may vary among fracturing fluids, flowback, produced water and recycled water. It was noted that watershed systems management requires knowledge of the pollutants that should be monitored. A participant stated that the identification and use of indicator compounds could improve the ability to monitor for key pollutants in watershed systems.

Chemical toxicity

EPA provided information to the participants about QSAR modeling, which estimates the potential chemical, physical or toxicological properties for a chemical based on the known relationship between chemical structure and toxicity of a large number of chemicals with known properties. At this point, EPA is not coupling concentrations of chemicals with their toxicity. EPA does not have complete and accurate information on concentration of chemicals in hydraulic fracturing fluid.

A participant noted that it is difficult to discuss toxicity without having concentration data to put it into perspective. A participant stated that as industry moves toward "green" fluids (e.g., chemicals that degrade more quickly), more of a particular chemical may be used because other, less "green" chemicals are not being used. It was also noted that industry is moving toward using chemicals in different forms (e.g., dry versus liquid chemicals), which may affect the concentrations and types of chemicals used and may change the toxicological effects of a spill (e.g., because of lower mobility).

Chemical concentration

The role of chemical concentration in screening and prioritization was discussed. Some participants expressed interest in volume data from flowback and its chemical makeup compared to produced water. A participant raised the question of what chemicals come into contact with the formation and whether they are being tracked as they come back out. A participant noted that the reaction of hydraulic fracturing chemicals with the formation might cause ground water contamination. EPA noted that the Marcellus Shale Coalition shared a report that included analyses of flowback and produced water. EPA would like to get additional flowback and produced water quality reports and samples that would allow it to fully assess the materials and their treatability.

Life cycle assessment (LCA), systems analysis and triple bottom line

Participants discussed the relationship of the study to a life cycle or systems approach. In the discussion, it was suggested that LCA is not within the scope of this study. EPA is focusing on evaluating potential impacts on drinking water resources now.

In its 2010 information request, EPA requested standard operating procedures and processes for deciding how the composition of fluid is decided upon, and changes to operations over time from service companies. Some participants noted that information available from development plans for field operations may be helpful in LCA, but these plans may change during actual operation. It was further noted that hydraulic fracturing activity is temporary, unlike typical industrial sites, and that metrics for evaluating hydraulic fracturing operations change. For example, operators may use a lower total volume of chemicals on a play basis, but on a per well basis the total volume of chemicals may not be trending down since the total number of wells is also decreasing as industry becomes more efficient in its well spacing. Industry also stated that the use of more chemicals could mean the potential for more reuse and recycling of water (i.e., increasing chemical use could increase the number of cycles in which the associated hydraulic fracturing water could be reused). A participant stated that operators need to balance all factors to come up with an optimum solution on a case-by-case basis. The basic considerations, it was noted, are cost, performance and "greenness." Industry considers LCA to be risk management, including all types of risk, which each operator has a different way of evaluating.

A "triple bottom line" analysis considers environmental, social and economic components. A suggestion was made to develop a tool to look at the triple bottom line by assigning values to social and environmental impacts. A participant also suggested adding "governance" as another factor, which would include regulations, how a company works and procedures for making decisions. A participant also suggested bringing real-world examples of a single operator in a single play over time to talk about LCA, to avoid having to talk in abstract.

3.3 Potential topics for future technical workshops

- Screening and prioritization of chemicals.
    - Discuss how to screen and rank chemicals.
    - Discuss how to define "green."
    - Discuss biodegradable chemicals.
    - Discuss chemical concentrations.
    - Consider toxicological work.
    - Are some chemicals obsolete (don't need analytical methods)?
- Life cycle assessment, systems analysis, triple bottom line.
    - This is beyond the scope of this drinking water study.
- Key indicator compounds for water systems.
    - Monitoring strategies (for public water supplies).
- Analytical methods (could be combined with the topic of key indicator compounds)

Some participants noted that monitoring, analytical methods and indicator tracers could all be addressed in one workshop.

Section 4. Well Injection Roundtable

4.1 Study overview

Jeanne Briskin, EPA's Hydraulic Fracturing Study Coordinator, provided an overview of EPA's progress in evaluating the possible impacts of the injection and fracturing process on drinking water resources. She presented two research questions:

1. How effective are current well construction practices at containing gases and fluids before, during and after fracturing?
2. Can subsurface migration of fluids or gases to drinking water resources occur, and might local geologic or human-made features allow this?

Ms. Briskin discussed the status of EPA's current work to answer these questions. She described EPA's data sources: literature review, service company data and well file data. She then described the following in detail:

- **Retrospective case studies.** The objective of these case studies is to determine whether drinking water contamination has occurred at the case study locations and, if so, to identify the cause of contamination. EPA solicited potential case studies from stakeholders and identified five studies based on specific criteria (e.g., geographic diversity, allegations). The five retrospective case studies chosen for review are Bradford County, Pennsylvania; Las Animas/Huerfano Counties, Colorado; Dunn County, North Dakota; Washington County, Pennsylvania; and Wise County, Texas. Ms. Briskin identified the list of analytes being monitored at these case study locations and noted that, where analytical methods are not verified, EPA would only use data in a qualitative manner.
- **Subsurface migration modeling.** In collaboration with Lawrence Berkeley National Laboratory, EPA is using numerical modeling of subsurface fluid migration scenarios to evaluate the potential for fluids (liquids and gases) to move from the fracturing zone to drinking water aquifers. EPA is using the Transport of Unsaturated Ground water and Heat (TOUGH+) model with a variety of enhancements.

4.2 Discussion

TOUGH+ model parameters, assumptions and scenarios

Participants offered a range of suggestions about the parameters and assumptions in EPA's fluid migration model. For example, individual participants discussed taking into account different well construction scenarios, fluid leakoff into the rock matrix during hydraulic fracturing, stress differences among geologic formations in the subsurface, geologic layering, natural vertical hydraulic gradient (the different pressures in the different geologic formations encountered in a wellbore), rock and fluid interactions, permeability and rock hardness, surface casing, and possible impact from drilling company errors or blowouts.

A participant stated that the diagrams for the model scenarios should be improved. It was noted that the system is not homogeneous; it frequently has many layers of variable geomechanical parameters between the fracture area and the aquifer.

Some participants also stated that the model should differentiate between initiating fluid movement along existing faults and contributing to existing fluid movement along existing fault. It was stated that it is difficult to determine the impact of the faults on fluid movement because there are many faults in the subsurface and their transmissibility may not be well understood.

A participant stated that fluid flows along the path of least resistance, and that could be the wellbore, not necessarily fractures. Furthermore, a participant stated, more desiccated and under-pressurized formations absorb fracturing fluids and may only produce back 10 to 20 percent of the water that is injected during hydraulic fracturing. This volume of fluid is important to account for in the models, according to the participant.

Some roundtable members recommended taking into account the bacterial degradation of organics and chemical reactions.[2] Some participants also suggested that EPA incorporate remediation and responses to issues into the model.

A participant stated that model uncertainties should be quantified, and suggested that EPA emphasize that the modeling question is a test of possibility, not probability. A participant also recommended that EPA consider Bayesian network modeling from a probabilistic approach to failure and contamination. Several roundtable participants noted that they would like to understand model sensitivity – how model outputs vary by changing input parameters – and they acknowledged that there are not many datasets available to which to compare these model results.

Tracking contamination from hydraulic fracturing

For tracking contamination from hydraulic fracturing, some participants suggested using reliable indicator compounds (e.g., total dissolved solids or chlorides) as an initial screening point; if the indicator is present, there is greater justification to increase the span of chemicals for analysis. Participants discussed the importance of measuring baseline conditions, which is planned for the prospective case studies. It was also stated that it would be useful to know what chemicals are used in different stages of well development, including hydraulic fracturing, as possible future indicators of drilling, completion and well operations impacts. A participant also noted that it is important to know the attenuation and breakdown products of the chemicals used in hydraulic fracturing. One participant asked whether it might be possible to use common indicators across the retrospective case studies.

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[2] EPA notes that the TOUGH+ models already account for fluid and heat movement, diffusion, sorption and decay. For more information about the TOUGH models, see EPA's *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report* (pp. 71-72) at www.epa.gov/hfstudy.

Potential sources of drinking water contamination

Participants discussed drinking water contamination due to hydraulic fracturing and other potential sources of contamination. Other potential sources raised included disposal wells including Class I injection wells, seasonal changes to surface waters concurrent with fracturing activities (e.g., runoff from road salt and deicers), natural gas and oil seepage, and septic tanks. Some participants noted that studies looking at the Catskill and Lockhaven formations suggest that isotopically thermogenic gas is generated in shallow formations. It was stated that data from Pennsylvania have shown background concentrations of methane in shallow drinking water aquifers up to 25 mg/L and in deeper aquifers up to 150 mg/L. A participant stated that methane in drinking water can be biogenic or thermogenic, and isotopic fingerprinting can be hard to interpret. A participant also stated that Pennsylvania regulators have not yet observed cases of methane contamination directly and solely attributable to hydraulic fracturing.

Cementing

Individual roundtable participants discussed the importance of cementing; one participant stated that, in Pennsylvania, poor cement jobs and not hydraulic fracturing are typically the cause of adverse impacts. A participant noted that cementation of casing in a well does not always isolate all the zones in the subsurface; bad cement jobs can allow leaks between zones. It was stated that cement can have a good seal at the bottom and top of a well, but not necessarily in the middle. Some participants warned of overreliance on cement bond logs, because of possible variations in interpretation; operators should also conduct casing pressure tests. Some participants also suggested that re-fractured wells be considered separately in the well file review because re-fracturing might affect well integrity. Other suggestions included monitoring the cement throughout the life of the well to detect degradation.

Well failure

Participants discussed what type of issue would constitute a well failure. A participant stated that when an oil and gas well is drilled, there are often multiple layers of protection; therefore, a series of failures may have to occur to cause actual contamination. It was noted that Pennsylvania has new regulations for mechanical integrity of wells, allowing regulators to quantify acceptable pressure and respond if wells fail to meet the standards.

Potential data sources

- Baseline data that industry collects to evaluate well siting (can be shared with EPA unless landowner contracts forbid it).
- U.S. Geological Survey background data.
- Baseline water well data collected by operators in Pennsylvania
- Data that Pennsylvania will be generating through its new well mechanical integrity program.
- Data that one participant can provide on the daily variation in gas content in water wells reflecting seasonal variations or water usage.
- Groundwater Protection Council information on stray gas (variability of data across timeframes).
- UIC program information about how injected fluids can migrate.
- Background information on natural gas seeps (e.g., in the Catskill and Lockhaven formations).

- A U.S. DOE dataset from Colorado with rock properties, mud weight and pressure measurements.

4.3 Potential topics for future technical workshops

- Evaluating the assumptions and parameters for the model scenarios.
- Understanding Interactions between faults and siting of wells.
- Understanding pressure gradients.
- Understanding background conditions and variability, including variability across regions.
- Accounting for local conditions and state regulations.
- Evaluating well construction and integrity.

Section 5. Flowback and Produced Water Roundtable

5.1 Study overview

Jeanne Briskin, EPA's Hydraulic Fracturing Study Coordinator, gave a presentation about flowback and produced water to introduce the topic. Ms. Briskin discussed research underway at EPA to answer four research questions:

1. What is currently known about the frequency, severity and causes of spills of flowback and produced water?
2. What is the composition of hydraulic fracturing wastewaters, and what factors might influence this composition?
3. What are the chemical, physical and toxicological properties of hydraulic fracturing wastewater constituents?
4. If spills occur, how might hydraulic fracturing wastewaters contaminate drinking water resources?

Ms. Briskin addressed the current status of EPA's work aimed at answering these research questions. She also described EPA's data sources: literature review, analysis of data from hydraulic fracturing service companies and well file review. Ms. Briskin then discussed the study in detail:

- **Spills database analysis.** The objective of this analysis is to assess the frequency, severity and causes of spills associated with hydraulic fracturing, EPA is reviewing five state databases (Colorado, New Mexico, Pennsylvania, Texas and Wyoming) and one federal database (National Response Center) for spill data associated with hydraulic fracturing. Ms. Briskin noted that Texas did not have an accessible public database with spills information and the Wyoming Department of Environmental Quality database did not provide enough information to identify incidents as hydraulic-fracturing-related violations.
- **Retrospective case studies.** The objective of these case studies is to determine whether drinking water contamination has occurred at the case study locations and, if so, to identify the cause of contamination. EPA solicited potential case studies from stakeholders and identified five studies based on specific criteria (e.g., geographic differences, allegations). The five retrospective case studies chosen for review are Bradford County, Pennsylvania; Las Animas/Huerfano Counties, Colorado; Dunn County, North Dakota; Washington County, Pennsylvania; and Wise County, Texas. Ms. Briskin identified the list of analytes being monitored at these case study locations and noted that, where analytical methods are not verified, EPA would only use data in a qualitative manner.

5.2 Discussion

Spills database analysis

EPA noted that spills are universal across industries; with limited resources, EPA is focused on the number and severity of spills associated with hydraulic fracturing, not the impacts of spills, which have been extensively studied elsewhere. EPA also noted that, because the national and state spills databases only contain information about spill sizes above the reportable limit, it can only assess frequency with spills with sizes greater than those limits. EPA asked whether each state has good information on spills and the effectiveness of the responses. A suggestion was made to ask industry for standard operating procedures for addressing spills under the reportable limit. EPA noted that it would be helpful to get flowback samples from operating wells starting when the well was fractured and continuing over time to see how the constituents and properties change over time.

A participant suggested two ways to obtain spill data:

- Ask oil and gas well owner/operators for daily operations reports, which include every incident that occurs with the date of occurrence.
- Get information from vendors whom the operators use (e.g., service companies that provide chemicals or pump flowback).

It was stated that, if service companies show up in a search of incidents, that would raise a concern. A participant responded that his company would be happy to work with EPA to share information to work through a spill or incident, especially if EPA said they were going to use the spill data as part of this study.

A participant stated that some states have more involved local governments than others. For example, in Pennsylvania, there is a push to improve reporting processes and recognition that regulations are evolving (e.g., reportable quantities are getting lower all the time).

It was noted that every publicly traded company has an incident tracking program, but every company has different words to describe its data, so it is difficult to compare across companies (e.g., classification of a spill as brine, water, or slickwater spill may vary across different operators, regions and staff members). Regarding a mechanism to coordinate terms across industry, it was noted that different groups have tried to come up with performance metrics, but have not been able to compromise; it is difficult to force large, international companies to use the same jargon as small companies. A participant suggested that a good place to help establish consistent terminology might be state regulatory agencies.

A participant suggested focusing on low-probability, high-impact situations (i.e., larger incidents) as well as low-impact situations. A company has provided EPA with data from its "worst incident," which included failure of the flange right below the wellhead.

A participant stated that climate change might affect the severity and frequency of spills from wastewater storage pits. In the future, it was noted, there may be higher volumes of runoff and larger floods, which will result in a need for improved water management and containment design.

Five retrospective case studies

In response to participant questions, EPA noted that it has an extensive quality assurance/quality control program and that the Director of EPA's National Risk Management Research Laboratory oversees all the case studies. The laboratories conducting the study operate under strict conditions and are periodically checked and data are sent to an external, independent auditor. EPA also noted that there is continuity of personnel for the five case studies. EPA is starting with the complaint associated with the five case studies and working backwards to determine whether or not the complaint was potentially from a spill or other cause. A participant suggested using results of EPA's case studies to define future prospective case studies that would represent different basins, plays, etc. These case studies, it was noted, could also help define monitoring strategies and EPA's future research plans.

Case study sampling efforts

EPA chose sampling points based on the locations of previous complaints and, within that area, at convenient, relevant places to take samples (e.g., streams, drinking water wells, ponds). EPA evaluated sampling results and detection of analytes and will identify whether to drill monitoring wells to better understand the causes of the detections. EPA is working with the U.S. Geological Survey, individual states and EPA regional offices to evaluate baseline conditions that are described in the 2012 Progress Report.

EPA confirmed that all samples during a round of sampling are taken at one time for a given site. EPA plans to periodically obtain multiple rounds of data from the same location. The initial data so far will be used inform where to sample next and are not yet sufficient to draw conclusions.

A participant suggested that EPA start sampling at hydraulic fracturing sites and well pads and work outward from there. EPA replied that it was not taking that approach because the Agency is not assuming that any detections are necessarily associated with the nearby wellpads. Several participants noted that their companies had information that may help others learn from their failures, rather than limiting EPA's investigation to looking at allegations. Another participant recommended John Wilson's "Compound Specific Isotope Analysis" document.

Wastewater characteristics

A participant stated that companies are trying to identify how to treat wastewater by first identifying what is in it. Industry should have data available that could be provided to EPA if industry identity could be masked. EPA is interested in these data as long as there is enough information to describe the samples. It was stated that it is difficult to characterize produced water in a generic sense because it varies from site to site and region to region; FracFocus may contain data on volumes of freshwater, brine and recycled water used to formulate hydraulic fracturing fluids. One participant recommended combining aquifer materials with hydraulic fracturing fluids in a temperature-controlled environment to study the changes (e.g., thermodegradation of hydraulic fracturing fluids). EPA's initial research plan included a similar study; however, because similar work is being done at DOE and EPA does not have core samples to conduct the research, EPA has dropped this project from the study.

A suggestion was made to consider the number of times the water has been recycled when identifying the quality of the water. A participant also suggested getting a sense from industry about how much water is pure versus recycled. Is there a trend to using less pure water?

State regulations

Participants discussed federal and state regulation of produced water and flowback. A participant asked whether EPA regulates produced water and/or flowback, or if that is left to the states. EPA has established nationally applicable technology-based discharge requirements for most oil and gas discharges under 40 CFR Part 435. These requirements must be incorporated in National Pollutant Discharge Elimination System (NPDES) permits that are issued by EPA or the states. Under Part 435, direct dischargers of oil and gas wastewaters are subject to zero discharge requirements. Zero discharge requirements can be met in a number of ways, including through underground injection of wastewater in disposal wells, which are subject to EPA's Class II UIC regulations at 40 CFR Part 144. 40 CFR Part 435 does not currently include categorical pretreatment standards for indirect dischargers to publicly owned treatment works (POTWs). One participant stated that there is heterogeneity in the type of regulating that is done if it is left to the states and streamlining regulations is important.

Defining key terms

A participant clarified terms from industry's standpoint: hydraulic fracturing fluid is fluid that is pumped down into ground; produced water is any water produced from the wellbore; and flowback is water in the initial phase of produced water. EPA noted that it recognizes that different people use different definitions for flowback and produced water. EPA groups flowback and produced water together as "wastewater."

Additional state databases and search terms

EPA asked whether there are additional state databases that EPA can pursue to augment those of Texas and Wyoming, which were identified as not having useable hydraulic fracturing spills data, and whether participants could propose additional search terms. Individual participants identified the following additional data sources: a Groundwater Protection Council report about risks of spills, the Texas Railroad Commission spills database, a Wyoming Oil and Gas Commission database, Alabama's spills database, offshore general permit data, and Shale Water Research Center data from Rice University and Washington University in St. Louis, Missouri. Some participants suggested the following additional search terms: "manifold," "slick water" and "corrosion."

5.3 Potential topics for future technical workshops

- Five retrospective case studies.
- Compound-specific isotope analysis.
- Analytical methods.
- Monitoring and monitoring strategies.
- Use of case studies to design of future monitoring strategies.
- Indicator parameters.
- Residuals.
- States' management of hydraulic fracturing wastewater.
    - Broad overview of the rules and regulations in each state.
    - Categorical pretreatment standards to regulate produced water discharges.

Section 6. Wastewater Treatment and Waste Disposal Roundtable

6.1 Study overview

Dr. Christopher Impellitteri, Chief of EPA's Water Quality Management Branch, provided an overview of EPA's progress in studying wastewater treatment and disposal issues. Dr. Impellitteri noted that this portion of the study focuses on the treatment and disposal of flowback and produced water. For the purpose of the study, EPA is not distinguishing between flowback and produced water.

Dr. Impellitteri presented the following research questions:

1. What are the common treatment and disposal methods for hydraulic fracturing wastewaters, and where are these methods practiced?
2. How effective are conventional POTWs and commercial treatment systems in removing organic and inorganic contaminants of concern in hydraulic fracturing wastewaters?
3. What are the potential impacts from surface water disposal of treated hydraulic fracturing wastewaters on drinking water treatment facilities?

Dr. Impellitteri discussed the status of EPA's current work to answer these questions. He described EPA's data sources: literature review, well file review and FracFocus. He described the laboratory and field studies relevant to wastewater in detail:

- **Wastewater treatability studies.** This project focuses on determining effectiveness of treatment methods used by POTWs and commercial wastewater treatment facilities (CWTs). EPA is researching the fate of pollutants, including partitioning of pollutants. EPA will also attempt to identify impacts from hydraulic fracturing wastewater on treatment processes (e.g., what TDS levels cause problems with biological treatment processes).
- **Wastewater treatability studies – residuals.** EPA is examining the concentration and types of contaminants in residuals. The current work focuses on determining the methodology for handling samples with high salt content using the inductively coupled plasma (ICP) analytical method (SW-846 Method 6010C) for metals. EPA is developing sample handling procedures (including some in situ techniques).
- **Surface water modeling.** EPA is evaluating conditions under which drinking water treatment plants that are downstream from discharges of treated hydraulic fracturing wastewaters may experience elevated levels of bromide or radium. EPA is developing Monte Carlo simulations and comparing the results to an empirical model, EPA's Water Quality Simulation Package (WASP).
- **Source apportionment studies.** To allow identification of whether water samples may contain constituents from hydraulic fracturing operations, these studies are identifying distinctive characteristics (bromide, chloride, other inorganic constituents) for different source types that discharge to rivers (e.g., hydraulic fracturing wastewater, coal-fired power plant wastewater). In particular, EPA is characterizing two Pennsylvania rivers that also have other inputs (e.g., power plants, wastewater treatment plants, acid mine drainage [AMD]) by collecting composite samples of the discharges into the river.

- **Disinfection byproduct precursor (DBP) studies.** This research will examine the formation and nature of total trihalomethanes (TTHMs) in waters impacted by effluent discharge of treated hydraulic fracturing wastewater.

6.2 Discussion

DBP studies

A participant noted that a 2010 incident in the Monongahela River prompted concern about TDS and bromide, which had not been monitored previously. It was noted that Pennsylvania always had natural gas wastewater discharge, but the boom in shale gas was thought to be causing issues with scaling on industrial equipment and with DBPs, which prompted regulator attention. As part of its DBP work, EPA is starting with simple wastewater matrices and working up to the actual wastewater samples. EPA will not build rigorous kinetic models for the formation of DBPs. A participant noted that industry might be interested in helping with the validation by working with their commercial laboratories. EPA stated that validation by multiple laboratories would be helpful.

DBP issue in Pennsylvania

The DBP situation in Pennsylvania is complicated due to the other sources entering the river; EPA is trying to resolve this issue through the source apportionment studies. Carnegie Mellon University (CMU) is studying bromide levels in the Monongahela River and the Ohio River Sanitation Commission (ORSANCO) is studying bromide levels in the Ohio River between Pittsburgh and Louisville. There may be an interest in also studying smaller tributaries in watersheds where smaller tributaries serve as drinking water sources.

A participant noted that the Pennsylvania oil and gas data system shows that there was no unconventional brine sent to POTWs in 2012 and that most discharges to POTWs ended in 2011, and wondered if the data capture this. EPA is currently working with two plants that treat oil and gas wastewater and discharge to Pennsylvania surface waters. EPA is also working with a reuse facility using a coagulation/flocculation process with additional filtration; the treated water is sent back to a lagoon and then reused for hydraulic fracturing. The NPDES permits for the two discharging facilities will be reassessed next year. One of these plants may convert to reuse by adding an evaporation process.

Source apportionment issues

Some participants discussed the difficulty of determining the source of contaminants in watersheds. For example, a participant noted that chloride in road salt could be a potential source. EPA would like to link the surface water modeling, source apportionment and DBP formation studies that were described in the presentation and obtain actual data for chlorides in water from road salt, particularly in the source apportionment study. All data would then be used in surface water modeling.

A participant noted that the study should address variability because there are multiple stressors on a watershed, and recommended that EPA separate the various inputs. It was suggested that EPA review a 15-year U.S. Geological Survey study in Utah in areas with high oil and gas production. It was also suggested that the study results be statistically correlated to the impact.

Chemical toxicity

A participant stated that the toxicity of THMs is of concern. Because bromide has the highest toxicity, shifting to the formation of brominated methanes may be a human health issue. The participant asked if EPA is studying toxicities and has any information on quinolines/pyridines. EPA has not yet looked at toxicity issues; however, risks from THMs are well documented in the existing Safe Drinking Water Act regulations. A participant noted that work on shale oil from 30 years ago may be helpful with respect to organics issues.

Individual participants provided the following suggestions regarding chemical toxicity:

- There needs to be a way to characterize toxicity if the wastewater is going to be discharged or reused.
- The study should address the complexity and toxicity of organics. Mass spectrometry techniques for organics analyses should be included in the study.
- Reviewing overall toxicity and the effects of surface discharge on aquatic life could provide information on constituents other than bromide, chloride and sulfate.

Coalbed methane (CBM)

EPA noted that it has not included samples from CBM hydraulic fracturing in the study due to lack of availability. EPA is in discussions with Australia regarding its CBM data. It was noted that the Pennsylvania Department of Environmental Protection has a very limited CBM data set that EPA could review. The samples were collected from two facilities and were highly variable.

Energy required for water treatment

A participant suggested that EPA study the energy consumption of water treatment. Zero-liquid-discharge treatment, it was stated, is highly energy intensive. Industry typically uses gas that would otherwise be going to market to supply the energy for treatment.

Wastewater volume

A participant asked about information on the volume of water going to wastewater treatment plants. The participant felt that the progress report needed this context. EPA stated that the progress report will focus on the research project status and will not describe results. The volume of wastewater and the destination is not the report's focus. EPA recognizes the need to stay abreast as industry adapts and changes and is willing to discuss this issue.

Impacts of reuse and reinjection

Some participants expressed interest in all aspects of reuse, both the positive impacts of reuse of acid mine drainage and other waste streams (e.g., these waste streams are no longer flowing into rivers and are used for hydraulic fracturing) and the negative impacts on drinking water sources. EPA noted that this information is not currently in the study, but that it might be able retrieve this type of information from FracFocus. A participant suggested that EPA consider the effectiveness of treatment prior to reuse and the impacts of residuals generated. It was also recommended that EPA's study have a greater focus on the UIC program used to dispose of hydraulic fracturing wastewater and the long-term effects of this disposal practice, including pollutant migration issues.

Pretreatment standards

A participant noted that pretreatment could be a big issue. EPA staff noted that the Office of Water is continuing to move forward with developing pretreatment standards.

Regional differences

Some participants suggested that local factors affect the selection of hydraulic fracturing source water and the wastewater treatment and disposal options, and that these regional factors should be considered in the study. It was noted that the current research seems to be focused on Marcellus. In the west, industry is using injection or ponds to manage wastewater. EPA will be meeting with contacts in western regions of the United States regarding wastewater treatment issues.

A participant stated that, as an example of how local factors play into the selection of hydraulic fracturing source water and wastewater disposal method, one company has been able to use brine from a saltwater zone above the shale zone for hydraulic fracturing. It was stated that fifty percent of the water used in fracturing is recovered and put back into the salt reservoir, reducing the environmental footprint, need for fresh water and water management costs (e.g., eliminated transporting water). However, it is not an option in other areas; one solution will not fit all in shale development.

It was stated that Pennsylvania does not allow discharge of hydraulic fracturing wastewaters to POTWs. A participant said that the oil and gas reports on Pennsylvania's website are a good source of data on where the water used for hydraulic fracturing originates and where it is disposed of. It was noted that in Pennsylvania, the volume of unconventional oil and gas wastewater sent to both POTWs and CWTs in the state is trending downward and recycling of wastewater has increased (approximately 90 percent). Pennsylvania is moving toward zero liquid discharge, through treatments that can include anything from simple storage of wastewater to storage and blending to treatment including chemical precipitation, reverse osmosis and/or crystallization.

A participant recommended that EPA consider the regulatory programs in states other than Pennsylvania; topics that are no longer issues in Pennsylvania may be issues in other states.

Future discharge trends

Several participants offered suggestions regarding future discharge trends and stated that companies will continue to look for new ways to economically manage their waste:

- It was suggested that EPA determine when produced water volumes will exceed the potential for reuse, which could lead to a future need for discharge. Many factors affecting gas and water production (e.g., gas price, gas demand, drilling activity, amount of water remaining in formation, company specifications for hydraulic fracturing fluid) will affect disposal options. Reuse assumes that new wells will continue to be drilled and require water for hydraulic fracturing.
- It was also suggested that EPA collect information on the rates of new investment in oil and gas and the overall lifetime of the industry. Companies are continually revising the modeling they use to make development projections and review information on the full life cycle, including water disposal.

- Although two to three dozen different water treatment processes are currently being investigated to treat wastewater, most are a variation on a small number of treatment technologies. In general, treatment involves eliminating the water resulting in a salt waste stream. These treatment options could be feasible at the end of the development process when reuse is not an option (e.g., use the energy-intensive options at the end of life).
- Other factors will also impact future wastewater management and disposal options, including potential regulatory drivers, regional differences in available management methods, geological constraints (e.g., lack of formations to receive wastewater in Pennsylvania), and capacity for reuse. There are different risks in different parts of the country.

6.3 Potential topics for future technical workshops

- Trends in treatment, recovery and wastewater management.
  - Reuse/recycling.
  - Zero liquid discharge.
  - Disposal of solids (treatment residuals) in landfills.
  - Energy use required for treatment.
  - Energy/water nexus.
  - Effects of radioactivity and salt in effluents on downstream drinking water treatment processes.
  - Use of other water management methods (e.g., ponds).
  - Radiological issues associated with water management methods.
  - Effectiveness of UIC Class II Program in handling hydraulic fracturing wastewater. (Is the current program working? Are contaminants migrating? Note that this topic is beyond the scope of the current EPA research study.)
- Status and development of wastewater treatment (industry projections).
  - Project the wells, water, flowback, disposal methods and treatment needs to understand the effects of future trends in the industry on the environment.
  - Look at the many factors affecting gas and water production (e.g., gas price, gas demand, drilling activity, amount of water remaining in formation, company specifications for hydraulic fracturing fluid), which in turn affects disposal options.

Section 7. Next Steps

Dr. Glenn Paulson, Science Advisor to the Administrator, provided closing remarks. He thanked the roundtable participants for this important conversation about the technical aspects of EPA's research study on the potential impacts of hydraulic fracturing on drinking water resources. Information sharing among technical experts from diverse backgrounds and interests is important to ensure that EPA has all the information it needs to provide the best available science. Dr. Paulson noted that this is the first step in a process that will continue over the next year to engage technical stakeholders with key expertise to help inform EPA's research study.

EPA will hold a webinar in late December 2012/early January 2013 to report on these technical roundtable meetings and the release of the study progress report.[3] EPA will select workshop topics from among those identified in the five roundtable discussions for a series of technical workshops beginning in February 2013. Workshops discussions will inform EPA on focused subjects integral to hydraulic fracturing to enhance the overall study, increase collaborative opportunities and inform possible additional future research. EPA will seek subject-matter experts to contribute to the workshops by providing technical knowledge during workshop discussions, and through selected invited presentations. Upon completion of the last technical workshop, EPA will reconvene the original roundtables to review the work addressed in the technical workshop series.

The Hydraulic Fracturing Study is one important step in gathering the scientific data necessary to help inform decision-makers responsible for ensuring the development of oil and natural gas reserves while protecting human health and the environment.

[3] Held January 3–4, 2013; slides and recording available at http://epa.gov/hfstudy.