

**Summary Minutes of the
U.S. Environmental Protection Agency
Science Advisory Board Hydraulic Fracturing Research Advisory Panel
Public Meeting, May 7-8, 2013
Westin Arlington Gateway Hotel
801 North Glebe Road, Arlington, VA, 22203**

Date and Time: Tuesday, May 7, 2013, 9:00 am – 5:15 pm; and Wednesday, May 8, 2013, 8:00 am – 3:00 pm ET.

Location: Westin Arlington Gateway Hotel, 801 North Glebe Road, Arlington, VA, 22203.

Purpose: The purpose of the May 7-8, 2013 public meeting was for individual members of the EPA Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel to provide expert comments on charge questions associated with the research described in EPA's *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report*, which was released in December 2012.

Participants:

SAB Hydraulic Fracturing Research Advisory Panel (See Roster with affiliations, Attachment A):

Dr. David A. Dzombak, Chair
Dr. Stephen W. Almond
Dr. E. Scott Bair
Dr. Peter Bloomfield
Dr. Steven R. Bohlen
Dr. Elizabeth W. Boyer
Dr. Susan L. Brantley
Dr. James V. Bruckner
Dr. Thomas L. Davis
Dr. Joseph J. DeGeorge
Dr. Joel Ducoste
Dr. Shari Dunn-Norman
Dr. Katherine Bennett Ensor
Dr. Elaine M. Faustman
Mr. John V. Fontana
Dr. Daniel J. Goode
Dr. Bruce D. Honeyman
Mr. Walter R. Hufford
Mr. Richard F. Jack
Dr. Dawn S. Kaback
Dr. Abby A. Li
Mr. Dean Malouta
Dr. Cass T. Miller
Dr. Laura J. Pyrak-Nolte
Dr. Stephen J. Randtke
Dr. Joseph N. Ryan
Dr. James E. Saiers
Dr. Eric P. Smith

Dr. Azra N. Tutuncu
Dr. Paul K. Westerhoff
Dr. Thomas M. Young

Drs. Susan Brantley and Thomas Young could not participate during the May 7-8, 2013 meeting. Dr. Laura Pyrak-Nolte participated on May 8th and not on May 7th.

EPA SAB Staff:

Mr. Edward Hanlon, Designated Federal Officer
Mr. Christopher S. Zarba, Acting Director, EPA SAB Staff Office
Mr. Thomas Brennan, Deputy Director, EPA SAB Staff Office

EPA Staff:

Ms. Ramona Trovato, EPA Office of Research and Development
Ms. Jeanne Briskin, EPA Office of Research and Development
Dr. Susan Burden, EPA Office of Research and Development
Dr. Lyle Burgoon, EPA Office of Research and Development
Dr. Christopher Impellitteri, EPA Office of Research and Development
Dr. Steven Kraemer, EPA Office of Research and Development
Dr. George Moridis, Lawrence Berkeley National Laboratory
Dr. Jennifer Orme-Zavaleta, EPA Office of Research and Development
Mr. Nathan Wisner, EPA Office of Research and Development (via teleconference)

Other Attendees:

A list of persons present at the meeting, who requested information on accessing the teleconference line or live webcast, or who noted via email that they participated on the live webcast, is provided in Attachment B.

Materials Available: The agenda and other meeting materials are available on the SAB website (www.epa.gov/sab) at the following SAB Hydraulic Fracturing Research Advisory Panel May 7-8, 2013 meeting webpage:

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

Meeting Summary

The meeting was announced in the Federal Register¹ and was conducted according to the meeting agenda.² A summary of the meeting follows.

May 7, 2013

Opening Statements

Mr. Edward Hanlon, the Designated Federal Officer (DFO), opened the meeting, and made a brief opening statement noting that the SAB Hydraulic Fracturing Research Advisory Panel is a Federal Advisory Committee operating under the Federal Advisory Committee Act (FACA). He noted the meeting was open to the public and that Agency-provided briefing materials were posted on the SAB website. He noted this was the first meeting of this Panel, and that Panel members were appointed as Special Government Employees to provide individual expertise and advice, not to represent any organization. He stated that the Panel members would provide their

individual expert oral comments on the following EPA document: December 2012 *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report* (EPA Progress Report). He stated that the goal for the May 7-8, 2013 meeting is for individual members of the Panel to provide expert science and engineering comments on charge questions associated with the research described in EPA's Progress Report. He also noted that since EPA's Office of Research and Development (ORD) requested a "consultation" on EPA's Progress Report rather than formal advice from the SAB, the Panel will not be seeking to identify points of agreement or consensus advice at this meeting. He stated that after the meeting, individual written comments from Panel members will be posted on the SAB website. He noted that eight members of the public had requested to present an oral statement during the May 7, 2013 meeting, and that six sets of written public comments for the May 7-8, 2013 meeting were received. He stated that the SAB Staff Office had identified no financial conflicts of interest or appearance of a loss of impartiality for any Panel members for this review. He also noted that minutes of the meeting were being taken to summarize discussions and action items in accordance with the requirements of FACA.

Mr. Chris Zarba, Acting Director of the SAB Staff Office, welcomed members of the public, Agency representatives, and Panel members, and expressed appreciation to the Panel and to the EPA staff for their support in preparing for the meeting. He noted that members of this Panel will provide independent expert advice at this consultation meeting and will deliberate as a group in the future when the Panel meets to review the Agency's draft Report on its research. He encouraged members of the Panel to be open minded and impartial as they provided their independent expert advice at this consultation meeting. He also noted that the SAB Staff Office recognizes the need to keep the Panel as informed as possible with new and emerging information related to hydraulic fracturing, and that after this meeting there will be opportunity for the public to provide such information to the Panel. He stated that the SAB Staff Office will provide notice in the Federal Register and post on the SAB website on opportunities for doing that. He also noted that the SAB Staff Office will make it a priority that the Panel will receive all the information it needs to do its work, and that if members of the public believe the Panel would benefit from briefings on particular topics that would assist the Panel in its work, to please contact the DFO, Edward Hanlon. He further noted that any briefings provided to the Panel would occur in a public forum and follow the procedures required by FACA to keep the public informed. Mr. Zarba noted that the SAB Staff Office determined that no Panel member had a disqualifying financial interest.

Dr. David Dzombak, Chair of the Panel, then welcomed everyone and requested that all members introduce themselves. Dr. Dzombak introduced Dr. Dave Allen, chair of the chartered SAB, who participated at the meeting via teleconference. Dr. Dzombak noted that he and Dr. Allen received a letter dated May 2, 2013 from Representative Chris Stewart, who is Chairman of the Environment Subcommittee of the U.S. House of Representatives Committee on Science, Space and Technology. He noted that the four-page letter provides a list of questions and topics for consideration by the SAB Panel and by the EPA as the EPA study moves forward. Dr. Dzombak noted that this letter was posted on the SAB web page on May 3 as part of the materials for the SAB Hydraulic Fracturing Research Advisory Panel May 7 meeting, and that Representative Chris Stewart would receive a formal response to this letter in the near future.

Dr. Dzombak stated the goals and objectives for the meeting, and noted that each Panel member will be providing their individual expert oral comments on ORD's charge questions during the meeting. He also noted that after the meeting, a compilation of individual Panel member comments would be posted on the SAB website, and a process-oriented letter would be sent to

the Acting EPA Administrator. Dr. Dzombak described the meeting process, and stated that within the agenda, two separate sessions for oral public comments would occur (one session after the first presentation by EPA, and one session at the end of the second meeting day for clarifying comments). Dr. Dzombak noted that a public teleconference of the Panel would occur on May 16, 2013 if there are additional public comments for Panelists' consideration that cannot be accommodated at this face-to-face meeting.

Dr. Dzombak then introduced Ms. Romona Trovato of the EPA ORD. Ms. Trovato presented PowerPoint slides³ that outlined EPA's research activities; the slides were provided on the meeting website. She commented that this SAB consultation was for EPA's Progress Report, and noted that in addition to consulting with SAB, ORD is conducting stakeholder engagement activities that include five roundtables and 3 technical workshops on analytical methods, well construction, and wastewater. She noted that ORD anticipated conducting two more workshops on water acquisition and water subsurface modeling.

A Panel member asked when data from ORD's research effort would be released to the public. Ms. Trovato responded that ORD's research data would be included in ORD's Report of Results that would be released in 2014. She also noted that upwards of 20 research papers would be prepared for peer review before the release of the report in 2014, and literature will be researched.

Another Panel member asked about the status of ORD's prospective studies on potential impacts of hydraulic fracturing on drinking water resources. Ms. Trovato responded that ORD was continuing to work closely with two companies to conduct these prospective studies, that there have been various complicating factors, and that these prospective studies will not be completed in time to be reported on in ORD's 2014 Report of Results.

Another Panel member asked how ORD planned to coordinate with the SAB Panel before December 2014 Report of Results was released for public review. Ms. Jeanne Briskin of EPA ORD responded that as ORD prepared papers for peer review, ORD may brief the SAB Panel. One Panel member asked how ORD manages to stay current on frequently changing hydraulic fracturing industry practices. Ms. Trovato responded that ORD's stakeholder engagement activities provided a mechanism to stay current on such practices, and noted that ORD also has been conducting webinars to keep the public informed on its activities. Ms. Briskin also noted that ORD released a Federal Register Notice in November 2012 inviting such information from the public, and that ORD recently extended the Federal Register Notice to allow more time for the public to provide such information to EPA.

Public Comment

Dr. Dzombak noted that it is important for the Panel to consider public comments, and that Panel members have the opportunity to ask clarifying questions of the public commenters. He stated that while the SAB is not obligated to respond to public comments received during its review, the Panel members should keep the public comments in mind and consider raising points made in public comments in their individual member comments as appropriate.

Ms. Elizabeth Tatham presented her oral statement as a stakeholder from Pennsylvania. She read from a statement³ that was posted onto the SAB meeting website after the meeting. Ms. Tatham commented that EPA's research on the potential impacts of hydraulic fracturing on drinking water resources should include information from site work and activities that have occurred at

the Dimock, Pennsylvania, and Pavillion, Wyoming hydraulic fracturing sites. She noted that information on groundwater contamination and toxicology has been gathered from these facilities. She commented that EPA should study the Dimock site further with additional testing as part of its research on potential impacts of hydraulic fracturing on drinking water resources. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Ms. Susan Carty presented her oral statement. Ms. Carty read from a statement⁴ that was posted onto the SAB meeting website after the meeting. She noted that she was speaking for herself as a citizen of Pennsylvania. She noted that while members of the public in Pennsylvania have serious concerns regarding its drinking water and other issues in the state, she would focus on the Pavillion, Wyoming hydraulic fracturing site. She commented that EPA's research and 2014 Report of Results on the potential impacts of hydraulic fracturing on drinking water resources should include information from site work and activities that have occurred at the Pavillion, Wyoming hydraulic fracturing site. She noted that the draft report for the Pavillion site indicated that EPA identified certain constituents in groundwater that are consistent with constituents used in natural gas work, including hydraulic fracturing. She noted that inorganic and organic compounds have contaminated water in the area and that gas production activities have enhanced release of these compounds. She noted that a large number of chemicals causing cancer were in groundwater at the Pavillion site, that EPA collected groundwater samples from 42 homes near the site, and that an article noted that chemicals such as benzene and phenol were detected in the groundwater. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Ms. Jessica Jones, representing the League of Women Voters of the United States, presented her oral statement. Ms. Jones read from a statement⁵ that was posted onto the SAB meeting website after the meeting. She commented that the League of Women Voters is concerned that hydraulic fracturing has occurred extensively and continues to occur in over 30 States without the completion of a comprehensive, transparent, science-based, peer-reviewed study on its potential impact on drinking water resources. She urged EPA to include a thorough examination of EPA's findings based on test sample analyses in two case studies: Pavillion, Wyoming and Dimock, Pennsylvania. She noted that these two sites are in different shale plays and both appear to have experienced water contamination, and that EPA investigations at these study sites are not included in the EPA's Progress Report. She requested that EPA's 2014 Report of Results address issues raised at these two sites in addition to the other previously selected sites. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Ms. Lynn Thorp, representing Clean Water Action, presented her oral statement. Ms. Thorp read from a statement⁶ that was posted onto the SAB meeting website after the meeting. She commented that Clean Water Action is concerned about the risks that hydraulic fracturing presents to drinking water and groundwater, and does not believe that current state or federal oversight of hydraulic fracturing is sufficient to prevent endangerment of underground sources of drinking water, contamination of surface drinking water sources, stresses on an already-constrained resource and other drinking water and ground water impacts. She noted that Clean Water Action supported EPA's research approach and consultation with the SAB. She noted that certain impacts from hydraulic fracturing were of particular concern to members of Clean Water Action and to the general public, and that these impacts should be considered before undertaking such activity. She noted that potential impacts of water acquisition on drinking water availability matter greatly to communities where drinking water sources are already stressed by drought. She noted that impacts associated with wastewater treatment and waste disposal can lead to

particular challenges to public water systems and the consumers they serve. She commented that if hydraulic fracturing wastewater contributes to the formation of disinfection byproducts in drinking water treatment plants, increased exposure and health risk to those drinking that water may occur. She also noted that potential impacts from insufficient well construction requirements and well failure associated with well injection activities include the possibility of subsurface migration of fluids or gases into underground sources of drinking water. She encouraged the Panel to look at the broader issues. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Mr. Daniel Sotelino, representing Natural Resources Defense Council (NRDC), presented his oral statement. Mr. Sotelino noted that NRDC strongly supports EPA's investigation of the potential impacts of hydraulic fracturing on water sources, and recommends that the study be as comprehensive as possible. He also noted that data to fully understand all risks associated with hydraulic fracturing are not available, and private enterprises are unlikely to gather and publish this information on their own. He noted that NRDC is concerned about reports of drinking water contamination occurring close to hydraulic fracturing sites and shortly after hydraulic fracturing has occurred. He commented that EPA should conduct or include additional studies or analyses in its investigation, including the following:

- Include old existing and re-fractured wellbores because wellbore integrity degrades over time, and older wells may have been constructed using less protective standards.
- Identify all practices actually used by industry and to what extent, to ensure consideration of real world risks to drinking water by the entire range of companies conducting hydraulic fracturing.
- Review the condition of wells before and after they are hydraulically fractured to fully understand the impacts of hydraulic fracturing on well integrity.
- Examine if and when companies use cement evaluation logs to verify surface and production casing cement integrity on hydraulically fractured wells.
- Examine the full range of possibilities for well failure in situations where the operator did not verify if the water protection string was set deep enough, or the operator did not verify the condition of well casing and cement prior to hydraulic fracturing an existing well.
- Use actual field data to calibrate EPA's reservoir simulation models and review industry's modeling efforts to identify modeling successes and needed improvements.
- Model incidents where water contamination, cement failure, and subsurface gas migration have occurred, and ensure that EPA's reservoir simulation models can predict and analyze such events.
- Model large scale and cumulative impacts of multiple hydraulic fracturing operations within a certain geographic area (which is the most realistic scenario), and model possible long-term transport and hydrogeologic changes, as outlined in recent comments from Tom Myers to the EPA.

Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Mr. Don Nevin, representing Lamnpipe, Inc., presented his oral statement. He discussed and referred to his handout⁷ which was provided to Panel members at the meeting, and was posted onto the SAB meeting website after the meeting. Mr. Nevin noted that Lamnpipe was formed two years ago to study the possibility of making high volume hydraulic fracturing processes safer by reducing the presence of certain toxic components in hydraulic fracturing flowback and produced water. He noted that Lamnpipe uses sand proppants that are coated to immobilize

certain constituents present in hydraulic fracturing flowback water. He stated that Lamnipipe's process is based on ion exchange and can separate and remove target ionic contaminants within the hydraulic fracturing cycle, including barium and radium compounds. The handout describes a method for keeping radionuclides out of hydraulic fracturing flowback and production water. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Mr. Jeff Zimmerman, an environmental lawyer representing Damascus Citizens for Sustainability, presented his oral statement. Mr. Zimmerman stated that Damascus Citizens for Sustainability was networking with members in 15-20 States. He commented that professional literature for the well industry indicates that between 5-6% of all wells fail. He stated that 6% of wells failed in 2009, over 8% of wells failed in 2011, and that all wells will eventually fail, with 50% failing in 20-30 years. He stated that the scenarios that the Lawrence Berkeley National Laboratory are considering for EPA's research should be expanded, since all scenarios described in EPA's Progress Report included wells cemented all the way to the ground surface. He commented that industry practices for hydraulic fracturing include installation of thousands of feet of uncemented portions of well bores, and that such bores are a pathway that should be added to the Lawrence Berkeley National Laboratory modeling effort. He noted that this modeling should also consider shallow wellgas releases, faulty joints and fractures in groundwater, since such scenarios create potential for contaminants and methane to move towards the surface (e.g., in Pennsylvania). He suggested that EPA should go to places where such releases are occurring and meet with members of the public who are dealing with this. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Mr. Peter Nara, representing Biological Mimetics Inc., was scheduled to speak at the meeting, but informed the Designated Federal Officer on May 7, 2013 that he could not present his oral statement.

Dr. Dzombak thanked the oral presenters. He noted that if any member of the public had a request to make clarifying comments at the end of the May 8, 2013 meeting of the Panel, to please inform the Designated Federal Officer Edward Hanlon of their desire to do so.

Process for Responding to EPA Charge Questions

Dr. Dzombak noted that ORD included twelve charge questions in its March 5, 2013 Memorandum to the SAB, and that ORD requested that individual members of the SAB Panel respond to these questions during the meeting and in their individual member written comments. Dr. Dzombak noted that the Agenda numbered the charge questions from 1 through 12, which matched the order the charge appeared in EPA's March 5th memorandum. He noted that Lead Discussants for each charge question would provide the initial lead comments to each question, and that after Lead Discussants provided their comments, comments from individual members of the entire Panel would be encouraged.

EPA Technical Presentation on Water Acquisition Phase of the Hydraulic Fracturing Water Cycle

Dr. Jennifer Orme-Zavaleta and Dr. Stephen Kraemer of EPA ORD presented PowerPoint slides⁹ on ORD's research on this phase of the hydraulic fracturing water cycle; the slides were provided on the meeting website. Dr. Orme-Zavaleta noted that ORD was considering recycling

of water in its research, and that ORD was conducting reviews of literature, well service records, FracFocus data, and information on well operations from 2009-2010. She also noted that ORD was conducting modeling efforts to assess this phase of research, and was assessing levels of certain constituents including total dissolved solids, chloride and bromide, and water quantity withdrawals and impacts on ground and surface water quality. She noted that ORD was assessing degrees of sensitivity at national, regional and local scales, and was assessing hypothetical scenarios through process-based modeling. She stated that ORD planned to calibrate its models using streamflow data from the U.S. Geological Survey (USGS). She noted that the Soil and Water Assessment Tool (SWAT) open source code watershed model would be used to assess the Colorado River Basin scenario, and the Hydrological Simulation Program Fortran (HSPF) open source code watershed model would be used to assess the Susquehanna River Basin scenario. She also noted that since there might not be sufficient model sensitivity at the national and regional level, ORD was focusing on local-scale modeling. She requested input from individual Panel members on its research approach.

One Panel member asked whether ORD was assessing changes in geochemistry resulting from water withdrawals. Dr. Kraemer responded that ORD was conducting a literature review to provide information on this linkage. A few members requested the criteria that ORD used to select two specific rivers for modeling, and why baseline modeling assessed potential impacts to landscape and cover but not ecology. Dr. Orme-Zavaleta responded that ORD has experience using the SWAT and HSPF models, and used that experience in identifying areas to model. She noted that ORD requested funding to assess other issues including potential impacts to air and aquatic media. Dr. Kraemer responded that ORD was focusing on effects of land cover on evapotranspiration, and how land and crop cover affects water balance.

Several Panel members requested more detail on ORD's modeling at national, regional and local levels, and noted that local scale modeling would have increased variance. Dr. Kraemer responded that ORD would like to assess modeling at the headwater scale. He also noted that the temporal scales for national and state water budgets were yearly, and that ORD was considering whether modeling at seasonal, weekly, and daily scales was feasible. Dr. Kraemer also responded that a significant challenge for both watershed models was how data availability would affect decisions on what is the appropriate scale of the models.

Several Panel members asked for more detail about the boundaries associated with ORD's watershed model, and one Panel member requested more detail on ORD's plans for model calibration and verification. Dr. Kraemer responded that the modeling included surface catchment and groundwater balance, and noted that the resolution of the upper portion of the model was more refined than the groundwater portion. He also noted that calibration and verification efforts would use stream data to assess the selection of parameters, and compare a prediction against data not used in the calibration.

A Panel member asked whether data from States and industry were available for EPA's modeling effort (e.g., State of Pennsylvania data on use of acid mine water for flowback water). Dr. Kraemer responded that data were being collected from both the States (Pennsylvania and Colorado). He noted that if data on use of Pennsylvania acid mine water were available, it would be taken into consideration in ORD's modeling effort. He also noted that scientists familiar with the Susquehanna River data were participating in ORD's June 2013 technical workshop.

A Panel member asked whether water uses other than for hydraulic fracturing were taken into account in ORD's modeling. Dr. Kraemer responded that ORD was relying on USGS's water

use data that took into account the major users of water.

One Panel member asked whether water quality modeling would be occurring. Dr. Kraemer noted that the modeling would not address water quality, and that ORD's literature review that would be reported out in ORD's 2014 Report of Results would assess water quality issues.

A Panel member asked whether chloride would be assessed in the water quality review. Dr. Orme-Zavaleta responded that ORD was discussing with stakeholders whether chloride or total dissolved solids should be assessed, and noted that ORD would report on this and other indicator constituents in its 2014 report. She noted that ORD sought Panel member input on which water quality characteristics should be considered in ORD's research.

Responses to Charge Question 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?*

One Panel member commented that EPA should model smaller scales, and noted that a key question was how to calibrate the models. The Panel member recommended that EPA consider options for this calibration as it moved forward with its modeling.

Another Panel member suggested that EPA's watershed modeling should be scaled based on historic levels that indicate realistic scenarios. In this way, the Panel member noted that modeling results can be aggregated. The Panel member suggested that historical data indicated that Hydrological Unit Codes (HUC) HUC-10 modeling assessments of withdrawals may be inadequate, and that HUC-12 modeling may be more appropriate to assess hydraulic fracturing withdrawal areas. The Panel member indicated that daily-scale models should be supported with daily or smaller timesteps, and smaller modeling scales were particularly recommended for analyses involving snowmelt. The Panel member suggested that ORD could potentially focus its watershed modeling analysis towards the late summer or early spring timeframe or on aquifers with high withdrawals due to hydraulic fracturing, and deemphasize modeling in areas involving lower withdrawals from hydraulic fracturing.

A Panel member recommended that ORD monitor industry practices closely, since industry is quickly adjusting its hydraulic fracturing operations and practices. Another member suggested that ORD's use of baseline modeling information is useful. The Panel member noted that it is important for ORD to consider statistical issues on data use and lack of information to support its full model development, and whether ORD has a complete dataset to conduct its analysis.

One Panel member noted that the USGS has 60 years of data in its database that ORD could use to project impacts. Another Panel member also noted that USGS has relevant activities related to water balance issues. One other Panel member commented that some operators have measured stream flow during their water withdrawals through use of USGS stream gage data, and noted that while such data may not have undergone a quality assurance process review, ORD may find it useful to consider such information. Dr. Kraemer noted that ORD was gathering USGS data on energy use statistics in the Marcellus shale, statistical models for flow in Pennsylvania, and water use statistics.

One Panel member noted that Figures 22 and 23 within EPA's Progress Report did not include wastewater treatment plants for intakes, and encouraged EPA to consider such intakes and how wastewater is used in these watersheds. The Panel member noted that the Figures also did not

include roads, and commented that water withdrawals may occur at major intersections of roads and rivers. The Panel member also suggested that ORD consider comparing winter operations to summer or fall, and how seasonal changes affected modeling results.

A Panel member recommended that ORD consider how population changes may affect water withdrawals. Dr. Kraemer responded that ORD was estimating this topic, including how changes in impervious surfaces may affect modeling results. Another member noted that the watersheds that ORD was modeling were controlled by reservoirs, and asked how the modeling accounted for this influence. Dr. Kraemer responded that ORD was assessing discharge from reservoirs in a fairly coarse manner in its modeling.

One Panel member commented that the modeling approach could be improved to better incorporate or differentiate groundwater impacts. The Panel member recommended that EPA's modeling approach differentiate impacts from hydraulic fracturing, agriculture, energy sources such as oil shale, spills, leaks, and other activities and issues. The Panel member asked whether ORD used a water quality component in the scenario modeling. Dr. Orme-Zavaleta responded that a water quality component was not incorporated into this model, and noted that the model assessed streamflow and discharge. Dr. Kraemer responded that other entities are exploring water balance issues associated with coal bed methane, tight sands, shale, and oil shale exploration and production activities, and that ORD would include this information within its literature search. He also noted that over the next year, ORD would consider applying water balance models in its modeling research. He further noted that ORD would try to differentiate fresh water and recycled water volume information in its analysis.

Another Panel member asked whether ORD would report its research on groundwater-dependent basins in its spatial distribution analysis in its 2014 Report of Results. Dr. Orme-Zavaleta responded that ORD may not be able to complete this part of the research prior to release of its 2014 Report of Results, and noted that ORD might be able to clarify this issue soon.

A Panel member commented that since ORD was assessing the impact of withdrawals on watersheds, ORD should also consider the effects of localized withdrawals and withdrawals for other purposes. The Panel member also asked whether ORD was considering rock stresses and changes in permeability in its analysis. Dr. Kraemer responded that over the next year, ORD would consider the shallow component of the groundwater/surface water interaction, and effects of storage on baseflow of stream flow, within the modeling. He noted that ORD's watershed models were not designed to assess local impacts, and that ORD may reassess this topic upon review of its modeling results. A Panel member commented that based on this discussion, ORD should use better tools to assess groundwater/surface water interaction impacts, noting that groundwater quality is a component of water availability.

One Panel member requested that ORD clarify how water use was accounted for in its modeling, and suggested that ORD's research results differentiate between consumptive use, total use, withdrawals, demands, evaporation effects, and other uses. The Panel member also noted that when presenting statistics on hydraulic fracturing, consumptive use may be only a portion of the total uses. The Panel member also noted that the interim progress reports that were referenced on page 93 of EPA's Progress Report should be included in ORD's report, since these interim progress reports were prepared in June 2012.

A Panel member noted that water source data were available on the FracFocus hydraulic fracturing chemical registry website, and asked whether this data was accurate. Another Panel

member asked how ORD was coordinating with state agencies to assess controls for water withdrawals. One Panel member asked whether ORD would plan to make the model data files available to the public in a usable format to allow the public to assess the model. Dr. Kraemer responded that ORD was closely coordinating with and using data available from states, and was investigating whether ORD could mine FracFocus data. He noted that ORD's Susquehanna River Basin modeling utilizes a low-flow tool, and that ORD was working with The Nature Conservancy to assess the impact of statistics and low flow on this modeling effort. He further noted that ORD would make the model data files available to the public in a usable format, after ORD completed a quality assurance process on that data.

One Panel member commented that it would be useful to apply stochastic approaches in modeling, particularly to assess uncertainty. The Panel member also asked whether data that collected from its roundtable meetings would be used by ORD. Dr. Orme-Zavaleta responded that ORD collected information from the roundtables and identified which roundtable presentations would be helpful to ORD, and noted that ORD's water acquisition roundtable will occur in June 2013.

Another Panel member encouraged ORD to consider how to present its data holistically using sound science, since the results of ORD's study is highly influential and the public will use this information for their own purposes.

Responses to Charge Question 1: Spatial and Temporal Scales for Water Quality Analysis:

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?

One Panel member commented that regarding ORD's modeling of small scale water availability, water quality within deep aquifers may not significantly change day to day, and water quality within surface water does significantly change on a daily basis. The Panel member noted it was thus important to model daily surface water impacts for at least some locations. The Panel member also noted that ORD should focus its efforts to collect lengthy daily scale historical data where such data are available.

Another Panel member noted that EPA has made significant progress in synthesizing information on chemicals used in hydraulic fracturing, chemicals within hydraulic fracturing wastewater, and whether hydraulic fracturing spills would contaminate drinking water resources. The Panel member commented that ORD's literature review was very important, and that this review must be scaled to allow other regions to be assessed and should include a synthesis of existing literature, primary and gray data. The Panel member also noted that the literature review should assess water availability impacts on local water supplies, and compare and assess which watershed models would be most appropriate to use. The Panel member stated that a significant question was what spatial and temporal scales should be considered by ORD in its analysis. The Panel member noted that while EPA's case study update indicated significant work has been completed, a significant amount of work has yet to be completed in the case studies. One Panel member noted there are a number of oil and gas company websites that note they conduct pre- and post-hydraulic fracturing water quality sampling. The Panel member suggested that ORD contact these companies to assess what data has changed over time.

Regarding spatial scale, several Panel members commented that ORD should collect multiscale data and conduct multiscale analyses. A Panel member commented that since the groundwater is heterogeneous, ORD should assess surface water, shallow groundwater, and deep groundwater

through multiscale analysis. The Panel member noted that the case studies are important and synthesize large amounts of historical data from numerous sources. The Panel member also noted that ORD should assess background water quality. The Panel member noted that some of the public commenters indicated that the public seeks data and analysis for certain locations such as the Pavilion, Wyoming site, and that it would be helpful if ORD could synthesize data from these locations and other smaller case studies and include these syntheses efforts in its reports. Another Panel member commented that ORD's multiscale analyses should assess effects from upward or downward hydraulic gradient, noting that water quality may change going downward as the density changes. The Panel member noted that many modeling exercises occur at small scale, and modeling at such smaller scale is important to do correctly. Another Panel member commented that ORD's multiscale analysis should be compatible with assessments of impacts from other activities such as from agricultural or deep mining uses. One Panel member noted that ORD should consider using the same spatial scales in its western United States analyses that are used for assessments conducted on water rights, agricultural water uses, and for other uses. Another Panel member commented that it is difficult to determine the appropriate scale for groundwater analyses since groundwater wells may sink into multiple aquifers, and blending changes over time. The Panel member noted that ammonia, methane and other gases may change depending on the groundwater layers. The Panel member further noted that studies in Kansas are assessing the differences in salt concentration over a 20-30 year timeframe in the groundwater. Ms. Briskin responded that ORD appreciates receiving information on case studies, and is planning to consider information from the literature as it develops its reports. She urged the public to bring this information to ORD's attention. She also noted that ORD would consider the Dimock, Pennsylvania, and Pavillion, Wyoming hydraulic fracturing site investigation information when those investigative reports are considered final.

A few Panel members recommended that ORD extrapolate data that it collects, and assess watershed impacts around wellheads. A Panel member commented that over 25 million instances of hydraulic fracturing have occurred across the United States, and some of these must be analyzed to make sure problems experienced at these locations are not replicated in the future.

One Panel member requested that ORD comment on the challenge of gathering available data from companies and state agencies. Another Panel member commented that while ORD's retrospective study conclusions to date have synthesized data, some conclusions note that ORD cannot differentiate heterogeneity and the importance of various sources of contaminants. The Panel member suggested that EPA conduct additional literature review to assess data variability and uncertainty, particularly in situations where significant long-term data is available. Ms. Briskin responded that ORD was assessing two types of case studies – retrospective and prospective. She stated that retrospective studies assess conditions at sites where hydraulic fracturing has already occurred, and that the public may have expressed concerns that their water may have been contaminated by hydraulic fracturing activities at such sites. She noted that ORD's prospective studies were occurring in areas where hydraulic fracturing has not yet occurred, and that the prospective studies would assess well construction and completion, and hydraulic fracturing activities, and how that technology affects that environment. She noted that ORD's efforts on the retrospective and prospective case studies included working with appropriate authorities and companies in nearby areas to understand the environmental facts associated with those areas. Ms. Briskin noted that in many cases, private companies have come out with EPA to take samples at these case study sites, and that state personnel were providing information on relevant studies in the area. Ms. Briskin noted that ORD was assessing five retrospective case studies. She noted that at these five sites, ORD's activities included assessing site hydrology and geophysics, site oil and gas history of activities, gathering sampling data, and

evaluating data and information to assess what further studies should occur. Ms. Briskin also noted that ORD would rely on information gathered from the oil and gas companies who operated in these areas.

Regarding temporal scale on water acquisition, one Panel member suggested that ORD use the same frequency for sampling that is required for public drinking water supplies (quarterly, monthly), and also conduct sampling and analysis for the same required constituents. The Panel member also noted that USGS regularly monitors certain constituents in surface water, and suggested that ORD consider adjusting its monitoring to be consistent with that USGS sampling. Ms. Briskin responded that for temporal scale analysis, the scientific purposes for ORD's studies may be different than the scale needed to supply public drinking water. She noted that ORD is attempting to assess potential impacts to drinking water resources at large scale in addition to local scale. Ms. Briskin also noted that ORD's modeling analysis is assessing how water withdrawals affect water quality, chemistry and geochemistry.

Another Panel member commented that a significant amount of literature has been published recently on releases of methane to groundwater due to drilling activity, and noted that the variability of methane concentrations in groundwater is an issue that ORD should consider. Ms. Briskin agreed that ORD should consider this issue.

One Panel member noted that a significant amount of data on hydraulic fracturing is available, and it is a difficult problem in determining which data to use in analyses. The Panel member expressed concern on how EPA would distill such huge datasets and consider data variability when assessing potential impacts to water resources across the United States. The Panel member noted that the State of Pennsylvania alone has thousands of hydraulic fracturing documents, and suggested that ORD consider assessing the data variability issue using this data, particularly when assessing water quality issues in shallow groundwater. Another Panel member encouraged ORD to release all data that it uses in its modeling effort, and to hone in on a few specific areas to document how removal of fresh water affects water quality.

One Panel member asked how ORD's model addressed the uncertainty associated with data changes over time. The Panel member noted that operational activities and procedures vary between hydraulic fracturing sites, and asked whether ORD's modeling effort accounted for such differences. Dr. Kraemer responded that ORD's modeling accounts for the latest state of practice for water reuse and capture, and that ORD was assessing uncertainty associated with these issues.

A Panel member suggested that ORD consider public health when determining which spatial/temporal scales should be considered in its modeling. The Panel member noted that ORD could use a risk assessment framework to assess which scales to consider, and develop a decision tree to assess the value of information when making a public health decision on water quality. Another Panel member suggested that ORD's analyses appeared to be primarily at the hazard identification stage within the risk assessment framework, and noted that matrices are available for assessing potential impacts at this stage. Dr. Orme-Zavaleta responded that ORD's analysis is not restricted to the hazard identification stage, and that ORD's 2014 Report of Results will provide information and a framework on how to assess the information it used to characterize potential impacts to drinking water resources.

Responses to Charge Question 2: Water Quality Characteristics: *Please identify the most important water quality characteristics that should be considered.*

A Panel member commented that there were three impacts on water quality: direct short- and long-term contamination; indirect impacts; and direct contamination from the source. The Panel member noted that water availability affects water quality, and that ORD should take a holistic view in assessing this. The Panel member noted that the American Petroleum Institute raised this issue in their submitted written comments. The Panel member also noted that ORD should assess global kinetic effects on basin responses in its research, since responses can happen in days or in decades or even longer. The Panel member also noted that ORD should incorporate degradation of the resource in its research, since water is only “quasi”-renewable, and water used for one purpose may be effectively removed for all time from being used for other purposes. The Panel member commented that a key question is whether using the water for hydraulic fracturing is the best purpose for use of that water. The Panel member noted that improved granularity was needed in FracFocus data on sources of water and water quality. The Panel member also commented that different hydraulic fracturing operations require different water quality.

The Panel member suggested that ORD should consider all sources of degradation of drinking water resources in its analyses (e.g., degradation of water resources from semiconductor factories, or from agricultural uses). The Panel member commented that ORD should also identify and assess potential long term effects associated with putting significant amounts of hydraulic fracturing materials into an ecological system. For example, ORD should consider long-term reduction-oxidation changes in water used or affected by hydraulic fracturing activities. The Panel member also noted that since today’s non-potable water may be tomorrow’s drinking water sources, it may be inappropriate to exclude water with total dissolved solids concentration greater than 10,000 mg/l from ORD’s analysis.

Regarding water balance, the Panel member also noted that a large percentage of hydraulic fracturing fluids may be left in the formation, and that ORD should appropriately consider this in its analyses. The Panel member suggested that ORD consider treating such formations as repositories for contamination (e.g., similarly as one would consider a nuclear repository). The Panel member also noted that small sources may have a significant impact on water resources.

One Panel member that ORD’s selection of characteristics to be considered in its analysis should be dependent on what data are available. For example, indicator parameters such as total dissolved solids, cations, and anions should be assessed; if other data are available, that data should also be assessed. The Panel member noted that Battelle collected data on a number of parameters and major cations/anions, and that data should be assessed. The Panel member also noted that it is important to consider water uses in the particular area being studied (e.g., if mining or agriculture occurs in that area, there may be some studies on how withdrawals for such uses may impact area water quality). The Panel member noted that such studies may be available for the Platte River in Colorado, and suggested that ORD note that water withdrawals are occurring for various uses.

One Panel member noted that acquisition can result in decreased groundwater or stream flow, and that EPA has tried to understand this phenomenon through its literature search. The Panel member noted that EPA suggests that decreased stream flow leads to increased stream concentrations. The Panel member commented that EPA should consider industry sources when assessing stream concentrations, and try to measure activities other than hydraulic fracturing that might impact surface water concentrations. Dr. Orme-Zavaleta responded that ORD’s

consideration of such sources would depend on what ORD finds through its literature analysis. Ms. Briskin noted that data from flowback water as reported within the Appendices of the EPA Progress Report indicated that wastewater contaminant levels are increasing.

The Panel member noted that Tables 30 and 32 of EPA's Progress Report indicate that public water supply withdrawals total 335 million gallons/day. The Panel member asked ORD how impacts from hydraulic fracturing could be specifically determined in consideration of such withdrawals. Dr. Kraemer responded that hydraulic fracturing is a small part of this analysis, and noted that these tables allow one to start to eliminate the type of impacts from other sources. Dr. Orme-Zavaleta responded that slide 6 of ORD's Presentation on the Water Acquisition Phase of the Hydraulic Fracturing Water Cycle indicated impacts from other sources and from other uses.

One Panel member commented that significant data were available for the effect of low flow and drought on water resources. The Panel member noted that arsenic concentrations increase as base flow goes down (e.g., Salt River in Arizona; rivers in southern California). The Panel member also noted that data on river concentrations of bromide, iodide, conductivity, hardness, and alkalinity have also been assessed in western drought conditions. The Panel member commented that these water quality effects that occur in the west could presumably occur from water acquisition. Another Panel member noted that high flows generally occur in Spring, and low flows occur the rest of the year. The Panel member suggested that ORD also consider the constant sources of contaminants into surface waters from acid mine drainage and from wastewater treatment plants. Another Panel member commented that in North Carolina, the drought in 2007 resulted in water quality downstream of wastewater treatment plants being significantly impacted and wastewater treatment plants had difficulties meeting discharge permit requirements.

A Panel member noted there may not be a significant amount of literature available on water withdrawal effects on water quality, and commented that ORD may need to collect their own data to assess this. The Panel member recommended that ORD focus on smaller basins within the Susquehanna River Basin analysis, and focus measurements on low flow periods when members of the public are withdrawing water from streams. The Panel member also recommended that water withdrawal wells in Texas and/or within the Balkan formation should be sampled for chemical analyses, and that ORD should resist sampling homeowner wells since there is uncertainty about how those wells are constructed.

One Panel member commented that the proposed reductions in the arsenic drinking water standard will affect the percentage of water supplies that may be affected by hydraulic fracturing activities. The Panel member also suggested that EPA gather data from Tribal nations, particularly in the southwest, to assist in its analysis. Ms. Briskin responded that ORD has consulted with Tribal nations during ORD's design of its study, during ORD's roundtables, and through individual consultations throughout the study. She noted that all of the summaries of these meetings with Tribal representatives are on ORD's website.

Another Panel member commented that EPA's Analytical Method 227 and Analytical Method 300 were available for use by ORD in its analyses.

One Panel member suggested that ORD further assess how poor quality water was being used in hydraulic fracturing operations. The Panel member noted that brine is being used in hydraulic fracturing operations in Ohio and Michigan, and that data has been collected and reported on the

concentrations of organic compounds in brine. The Panel member noted that USGS has a significant amount of data on the effects of groundwater withdrawals on water chemistry, through its 'RACIS' studies from the 1980's and 1990s.

EPA Technical Presentation on Chemical Mixing Phase of the Hydraulic Fracturing Water Cycle

Ms. Jeanne Briskin of EPA ORD presented PowerPoint slides¹⁰ on ORD's research on this phase of the hydraulic fracturing water cycle; the slides were provided on the meeting website. Regarding the research questions noted on slide 1 of her presentation, Ms. Briskin noted that there were four categories of secondary research questions that ORD was assessing: frequency of spills; chemicals that are spilled; properties of chemicals for such spills; and how to assess impact of such spills. A Panel member asked whether EPA has criteria specifying the volume of a spill. Ms. Briskin responded EPA's presentation on Flowback would discuss this topic.

Regarding slide 5, Ms. Briskin noted that EPA requested information on all chemicals used by the service companies, whether the chemicals were considered confidential business information (CBI), drilling well data, and data on sample formulations. She noted that the number of drilling wells that were included in this service company analysis was approximately 25,000. A Panel member asked whether the chemicals that were considered CBI have a minimal or significant effect on EPA's analysis. Ms. Briskin noted that Appendix A of EPA's Progress Report indicated that many companies who provided CBI allowed EPA to list those chemicals without indicating the company name. She noted that EPA made use of much of that CBI, and that EPA was still discussing the CBI with these companies.

Regarding slide 6, Ms. Briskin noted that service companies were not required to report proprietary information in their responses to EPA's inquiries for data, and that EPA did not receive information on concentrations of the individual chemicals used by service companies. She noted it was difficult to estimate concentrations of chemicals since volumes were reported in total gallons and ingredients were reported in mass. Regarding slide 7, Ms. Briskin noted that the FracFocus well locations depicted on the Figure overlap with locations of hydraulic fracturing shale plays.

Regarding slide 8, Ms. Briskin noted that approximately 350 well files were reviewed for locations indicated on the slide. A Panel member asked why it appeared that ORD was not reviewing well files for some counties, and whether there was any well file data available for these counties. Ms. Briskin responded that the nine companies provided data on 25,000 wells. She noted that ORD sought to conduct a representative analysis through stratified random sampling of this well data, and that ORD assessed 350 wells from this sample.

Regarding slide 11, Ms. Briskin noted that there may be a distinction between chemicals that are on the market, and chemicals used by stakeholders. Regarding slide 12, Ms. Briskin stated that EPA was assessing criteria for identifying indicator chemicals, and noted that indicators are useful since they are chemicals that are normally used in hydraulic fracturing and are not used as tracers. A Panel member asked why ORD was not assessing tracer chemicals. Ms. Briskin noted that ORD was focusing on data already available, and that some companies use tracers for their own purposes. She noted that at this time, EPA was not planning to conduct tracer studies.

Responses to Charge Question 4: Fluid Composition and Potential Impacts to Drinking Water Resources: *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?*

One Panel member commented that EPA's use of state and chemical databases may result in use of outdated data. The Panel member noted that the databases are sorted by the years 2005-2012, and that FracFocus data are from 2011-2012. The Panel member noted that Table 1 in EPA's Progress Report cited data from the 1990's, Table 2 cited 2004-2009 data, and Table 3 indicates detections of chemicals from data collected years ago. The Panel member noted that hydraulic fracturing fluid concentrations have changed very significantly over the past 10 years, particularly between 2009 and the present, and recommended that EPA develop a time bar that indicates the progression of hydraulic fracturing fluids to the present day, and the concentration changes of these fluids over time.

The Panel member commented that it was not necessary to identify concentrations of dioxins and halocarbons, and suggested that EPA consider assessing data on total dissolved solids and other conventional parameters to determine the presence of hydraulic fracturing chemicals. The Panel member noted that EPA could assess trends for hydraulic fracturing slick water, noting that these trends change depending on the function of the well. The Panel member commented that fluid chemistry in hydraulic fracturing wells drilled to 9,000-10,000 feet depth is affected due to changes in liquid temperature at depth, and that these changes should be accounted for in EPA's analysis.

A Panel member asked ORD to describe its strategy to identify which chemicals are of most concern and should be monitored. Ms. Briskin responded that ORD has not yet prioritized among chemicals of most concern. She noted that ORD was focusing on chemicals used in hydraulic fracturing operations or were indicated in hydraulic fracturing produced waters. Ms. Briskin noted that ORD would assess the physical/chemical/toxicological properties for those chemicals, and use quantitative structure-activity relationship models to estimate those properties. She also noted that ORD would use published toxicological data or computational toxicology to develop the toxicological values that would be used within this analysis. The Panel member commented that ORD could develop a list of chemicals that are safer to release into the environment than other chemicals. Ms. Briskin noted that ORD was using sound science in its analysis, and was aware of data provided by companies that will inform on chemical properties and toxicological values for chemicals used in the hydraulic fracturing process.

A Panel member commented that the American Conference of Industrial Hygienists (ACGIH), the National Institute for Occupational Safety and Health (NIOSH), and other sources can be useful to provide toxicological support and toxicological databases to assess toxicological information. Dr. Lyle Burgoon of ORD stated that EPA was reviewing a number of databases to gather toxicological information to support EPA's analysis, including EPA's Integrated Risk Information System (IRIS) database, other EPA databases, Agency of Toxic Substances and Disease Registry (ATSDR) databases, and other data. Dr. Burgoon further noted that the IRIS database provides oral reference doses and data for chronic oral exposure, reference concentrations for chronic exposure, and cancer slope factor information on chemicals of interest. The Panel member noted that EPA could use other databases for chemicals that EPA has not yet assessed. Ms. Briskin encouraged the Panel members to provide information on such databases to ORD, particularly on databases that provide peer reviewed data.

Another Panel member commented that EPA appeared to be doing a good job in identifying data quality objectives in its research. The Panel member asked why EPA was not developing a toxicological index for chemicals it identified within this research. Ms. Briskin responded that the development of such an index is not within the scope of EPA's current research, and that stakeholders have raised significant concern on which chemicals are being used and what information is available on these chemicals.

A Panel member asked whether there was uncertainty associated with components of FracFocus data. Ms. Briskin responded that components of FracFocus data had uncertainty, and that ORD would weight data that have been peer reviewed higher than data not peer reviewed (e.g., data from grey literature). The Panel member asked whether ORD was checking the FracFocus data for accuracy; Ms. Briskin responded that ORD was not checking FracFocus data and was using the data as is.

A Panel member commented that if EPA did not know what or how much chemicals are present, EPA will be less able to assess potential effects of hydraulic fracturing on drinking water resources. The Panel member noted that 44% of chemicals that EPA brought forth in its analysis were not within the Chemical Inventory System, and that there are over 400 chemicals in this group. The Panel member noted that if it is not EPA's responsibility to identify this information, this was extraordinary and a travesty. The Panel member recommended that EPA identify chemicals of interest associated with the potential effects of hydraulic fracturing on drinking water resources, sort these chemical by toxicological endpoint (i.e., cancer vs. non-cancer), and develop a toxicological index for these chemicals. The Panel member also recommended that EPA assess mixtures of chemicals and synergistic effects of chemicals that had potential effects of hydraulic fracturing on drinking water resources, and include both historic and new chemicals in its analysis, since many historic chemicals have previously impacted communities. The Panel member also recommended that EPA clarify how EPA sets discharge requirements for other industries, since technology-forcing requirements may limit risk impacts.

One Panel member noted that EPA needed information on dose to assess the potential effects of hydraulic fracturing on drinking water resources. The Panel member commented that it was important for EPA to gather information on the volumes of contaminants that are at hydraulic fracturing sites at any given time, how much containment is occurring on those contaminants, and whether the containment is used for storage. The Panel member noted that since many of the 1,000 chemicals of potential concern to EPA are common or similar to each other, EPA should consider sorting and identifying volumes of chemicals by class. The Panel member commented that EPA could identify which chemicals are below thresholds of concern so that it would not focus on those chemicals in its analysis.

One Panel member noted that the public comments mentioned that many hydraulic fracturing chemicals are used in trace amounts, and suggested that EPA collect this data. Ms. Briskin responded that ORD has made a public docket available so that companies and members of the public can submit detailed chemical data, including CBI data, to the EPA research study on hydraulic fracturing.

Another Panel member noted that EPA should consider the proximity of hydraulic fracturing wells to each other. The Panel member noted that states released a January 2013 report that contains data on hydraulic fracturing. The Panel member also noted that the State of Colorado is requiring every oil and gas company to report water sampling data within ½ mile of their hydraulic fracturing wells, and suggested that EPA use this information as it moves forward in its

research.

One Panel member commented that it was important to identify how the 1,000 chemicals used for hydraulic fracturing related to lifecycle use. The Panel member suggested that industry manage fear and inform the public on why industry uses the chemicals, and describe how to use these chemicals safely and responsibly. The Panel member asked how the Toxic Substances Control Act (TSCA) proposed regulations would be addressed in EPA's 2014 Report of Results. Ms. Briskin responded that ORD was conducting a scientific study to assess the potential effects of hydraulic fracturing on drinking water resources, and that ORD's study will be used by other EPA programs. She also noted that TSCA CBI regulations were followed for ORD's acceptance of such data.

One Panel member noted that EPA should identify formulations of chemicals being used in hydraulic fracturing operations, to help assess whether there is a trend in chemicals being used in these operations. Ms. Briskin noted that when requesting information from service companies, ORD asked what trends these companies had in their use of these chemicals. She also noted that ORD was also considering trends identified in the literature data on hydraulic fracturing chemicals in use. A Panel member noted that some organizations have assessed how to assess groups and mixtures of hydraulic fracturing chemicals, and suggested that EPA consider such approaches in its research.

Responses to Charge Question 5: Historical Changes and Current Trends in Fluid

Composition: *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 of EPA's Progress Report?*

A few Panel members noted that while the FracFocus hydraulic fracturing chemical registry is useful, additional information is needed to identify what chemicals are being currently used by the hydraulic fracturing industry. Another Panel member noted that while FracFocus data on the percentages of chemicals used may be proprietary, the companies can disclose the components of their mix. The Panel member noted that several Canadian provinces have mandated release of this information.

A Panel member suggested that ORD identify ways to identify and track how the industry is changing, particularly since much of EPA's data are from 2005, and will be 9 year old data when ORD releases its report on the results of its research on the potential effects of hydraulic fracturing on drinking water resources in 2014. The Panel member encouraged EPA to continue to reach out to drillers, operators, and owners of hydraulic fracturing wells and operations to receive current information. The Panel member noted there are many reasons why these wells are used, and ORD has a big challenge in closing the data gap between the data gathered through EPA's current search effort and the data that is currently available.

A Panel member suggested that EPA could possibly focus on three or four chemicals that are being currently used by the hydraulic fracturing industry, and identify how trends have changed in the use of those chemicals. A few Panel members noted that it is important to consider representative mixtures used by the hydraulic fracturing industry in this analysis.

A Panel member noted that EPA should consider the hydraulic fracturing data that EPA collected from service companies through a lawsuit that occurred in the early 1990's. The Panel member asked what percentage of wells that were hydraulically fractured are reported by the nine

companies from whom EPA requested data. Ms. Briskin responded that while she was not sure of the overall percentage of wells, data from approximately 30,000 wells may have been gathered from these companies. She noted that the nine companies were of different sizes. The Panel member noted that upon review of data from between 2002-2013, smaller “mom-pop” companies are getting into the hydraulic fracturing business, and large hydraulic fracturing companies have a smaller share of the total number of hydraulic fracturing wells currently being operated. The Panel member stated that there are significantly more than nine companies currently conducting hydraulic fracturing, and suggested that EPA collect information from these other companies.

A Panel member recommended that ORD assess the persistence of chemicals used during the period of time for which ORD collected data (e.g., 2005-2010), and assess whether these chemicals have a current potential impact to drinking water resources.

A Panel discussion occurred on the degree of treatment and use of recycled flowback water in hydraulic fracturing operations. One Panel member noted that current, new hydraulic fracturing wells are drilled at different depths and do not use recycled flowback water in the hydraulic fracturing process. The Panel member also noted that recycled flowback water used in the hydraulic fracturing process will have different concentrations of chemicals depending on the source of that recycled flowback water. A Panel member noted that recycled flowback water is only used at the same site where the flowback water is generated, and that hydraulic fracturing operators do not use recycled flowback water from other hydraulic fracturing jobs. One Panel member commented that hydraulic fracturing often occurs around a well pad comprised of a number of wells, and that water is reused in the same formation within/by these wells that are in the same formation. Another Panel member commented that in central Pennsylvania, there are centralized treatment facilities that treat flowback waters for reuse. One other Panel member noted it has been reported that in central Colorado, no fresh water is used in hydraulic fracturing operations, and therefore all water used in such operations must be recycled. A Panel member commented that the highest concentrations of contaminants in flowback waters occur at the initial stages of use of that well.

A Panel member commented that to help limit potential drinking water impacts, hydraulic fracturing operations must be predicated on good oilfield practices. The Panel member stated that wellsites must be designed and constructed to ensure that good barriers are in place to isolate the well from contents that may be released from that well, and monitoring must occur during the operation.

A Panel member commented that it is important to understand the concentrations of chemicals that are being used during hydraulic fracturing, and noted that companies change their mixes over time and depending on the location. Another Panel member noted that chemicals used in hydraulic fracturing wells in Wyoming are different than chemicals used in Pennsylvania wells. One Panel member noted that the list of chemicals that ORD included in Appendix A of EPA’s Progress Report provides helpful information on chemicals that go into hydraulic fracturing wells. The Panel member noted that of 930 chemical species listed in Appendix A, 33 are carcinogenic, according to an ATSDR database. The Panel member stated that most of these carcinogenic chemicals (e.g., benzene, toluene, ethylbenzene, xylene, and other chemicals) are being used less often over time in hydraulic fracturing operations. The Panel member also noted that hydraulic fracturing companies are stating on their websites that over time they are reducing their use of certain metals that make hydraulic fracturing fluids more viscous (e.g., lead, mercury, antimony). The Panel member suggested that EPA consider which chemicals included

in Appendix A were used 5-10 years ago, and are currently being used, to assess if fewer carcinogenic chemicals are currently being used. The Panel member also noted that several hydraulic fracturing companies are offering chemical mixtures that are ‘green’ mixes, and also are investigating use of ultraviolet light treatment technology in their operations.

A Panel member commented that ORD use groundwater monitoring to assess trends. The Panel member also noted that while there is a limited amount of data on the use of tracer chemicals over time in hydraulic fracturing operations, hydraulic fracturing operators are using tracers more over recent years.

Responses to Charge Question 6: Indicator Chemicals: *What criteria should be considered when identifying indicator chemicals, and why?*

Several Panel members commented that multiple indicator chemicals were needed to assess potential impacts of hydraulic fracturing on drinking water resources, and noted that stability and mobility are key characteristics for an indicator chemical and that toxicity should not be an important characteristic for an indicator chemical. A Panel member commented that while toxicity should not be a main driver on the selection of tracer chemicals, EPA should identify tracer chemicals for toxicologically important chemicals.

A Panel member noted that a chemical indicator should be stable; have known breakdown products; be mobile in the subsurface environment; be inexpensive to use; have available, valid analytical methods; and be specific to hydraulic fracturing operations. The Panel member noted that certain chemical additives used for hydraulic fracturing may be mobilized in the environment using a salt or another chemical, and literature has indicated that such chemical additives could be used as indicators. The Panel member also recommended that ORD identify and perform a trend analysis on baseline parameters that are specific to a particular geological formation (e.g., Marcellus Shale signatures), and specific to hydraulic fracturing operations (e.g., using isotopic ratios for chemicals used in the hydraulic fracturing process). The Panel member noted that since it may be expensive to perform such analyses, ORD should consider using a tiered approach for the selection of indicator chemicals (e.g., Tier 1 would analyze gross alpha and beta radiation; Tier 2 would assess additional parameters). The Panel member recommended that ORD consider seasonal variation and the practicality of gathering data for parameters being considered for being indicator chemicals. The Panel member also recommended that ORD consider whether and how the release of methane may affect the selection of an indicator chemical.

Another Panel member noted that Table 45 of EPA’s Progress Report provided ORD’s list of chemicals identified for initial analytical method development, and commented that this table helped the reader to understand the priority of chemicals specific to hydraulic fracturing and provided useful suggestions for prioritizing chemicals. The Panel member recommended that chemicals used in higher volume in hydraulic fracturing operations should receive higher priority than other chemicals, and recognized that such prioritization would necessitate having information on concentrations of chemicals prior to their use in hydraulic fracturing operations for an area. The Panel member also noted that EPA should consider prioritizing hydraulic fracturing chemicals that are mobile in the environment. The Panel member stated that information generated through this prioritization effort should not be expected to be usable for risk assessments, and that toxicity information should not be factor in assessing priority of chemicals for initial analytical method development. The Panel member also asked how pH should affect the priority of chemicals for initial analytical method development.

A Panel member suggested that glycols would serve as good indicators for hydraulic fracturing activities. The Panel member suggested that indicators should be formulated on a regional basis, and commented that since many potential indicator chemicals are found in flowback waters, it will be difficult to narrow down the source of these chemicals. The Panel member suggested that EPA consider use of stable isotopes to identify a signature from a specific well. The Panel member recommended that EPA identify classifications of chemicals with different fate/transport properties that EPA is considering for potential tracers, and identify representative tracer chemicals for each class of chemicals.

Another Panel member suggested that EPA should not choose tracer chemicals that are common groundwater constituents, and should choose chemicals that are traceable within shallow groundwater intervals. The Panel member recommended that EPA select tracer chemicals that will indicate the presence of higher concentration chemicals.

A Panel member commented that while EPA's Tier 1 and Tier 2 tracer compounds as indicated in EPA's Progress Report appeared to be generally appropriate, five of EPA's suggested tracer chemicals (total dissolved solids, iron, total kjeldahl nitrogen, organic carbon and potassium) are inappropriate tracer chemicals since these chemicals are not specific to hydraulic fracturing.

EPA Technical Presentation on Flowback and Produced Water Phase of the Hydraulic Fracturing Water Cycle

Ms. Jeanne Briskin of EPA ORD presented PowerPoint slides¹¹ on ORD's research on this phase of the hydraulic fracturing water cycle; the slides were provided on the meeting website. Regarding slide 1 of her presentation, she noted that flowback water and produced water are defined differently, and that the definitions for these waters is noted in EPA's Progress Report. Regarding slide 2 of her presentation, Ms. Briskin noted that ORD was using data from industry to assess hydraulic fracturing wastewaters.

Regarding slide 3, a Panel member asked what type of literature ORD was soliciting from the public. Ms. Briskin responded that ORD was seeking data that followed documented quality assurance/quality control procedures. A Panel member asked whether information on slide 5 was provided in EPA's Progress Report. Ms. Briskin responded that while the table on slide 5 was new and not presented in EPA's Progress Report, the data that supported the table are provided in an Appendix of EPA's Progress Report.

Regarding slide 6 of her presentation, Ms. Briskin noted that the data points on the figure are from nine drillers who sent data to ORD. Regarding slide 11 of her presentation, Ms. Briskin noted that ORD gathered data from the states indicated in the figure. Regarding slide 13 of her presentation, she clarified that injection well disposal spill data were associated with wells receiving wastewater. She commented that ORD was assessing if spills get past a barrier at locations where spills have been reported, and focusing on the total number and size of reported spills.

A Panel member asked why ORD was not assessing air releases from volatile compounds used in hydraulic fracturing. Ms. Briskin responded that ORD was collecting information from databases on identified chemicals and was assessing the lifecycle of these chemicals.

Another Panel member noted it is difficult to differentiate whether a spill caused a release of

chemical. The Panel member asked how common these spills are. Ms. Briskin responded that EPA is assessing data on the frequency and timing of spills. One Panel member noted that previous SAB Panels and members of the public commented that flowback and produced waters that are managed on the ground surface have the greatest potential for potential impacts to drinking water resources.

A Panel member asked why EPA was not interested in assessing deep well injection spills. Ms. Briskin responded that ORD needed to define boundaries for the research effort, and that spills associated with those wells were excluded.

A Panel member asked whether ORD was collecting the State of Pennsylvania Department of Environmental Protection data on hydraulic fracturing; Ms. Briskin responded in the affirmative. Another Panel member asked whether ORD was using key word searches within available databases to identify whether a hydraulic fracturing spill occurred. Ms. Briskin responded that ORD was striving to use a clear, well documented, and unbiased approach in how it assesses data collected from these databases. A Panel member asked whether hazardous and reportable data were provided by states. Ms. Briskin responded that the types of data available are database-dependent.

Responses to Charge Question 9: Composition of Flowback and Produced Water:

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

A Panel member commented that while all data on the composition of flowback and produced water may not be available, EPA has identified the primary sources of available information. The Panel member noted there are a growing number of Society of Petroleum Engineer (SPE) publications on this topic, and that it is challenging to analyze these papers because they focus on particular issues. The Panel member noted that companies may not have an economic driver to analyze their flowback water. The Panel member commented that Table 3 in EPA's Progress Report indicates that a significant factor in the selection of chemicals of concern is the concentrations of such chemicals. The Panel member noted it was challenging to assess potential impacts through such a selection process since there are differences in standards and levels of concern associated with these chemicals. The Panel member recommended that EPA consider analyses that compare basins by basins and region by region in order to identify a spatial context associated with such chemicals. The Panel member also recommended that ORD consider whether the disposal of large volumes of flowback waters relate to levels of seismicity. Ms. Briskin responded that seismicity is beyond the scope of EPA's research effort, and that USGS is considering the seismicity issue associated with injection of hydraulic fracturing wastewater.

A Panel member commented that paper copies of data collected from pressure safety flow impact analyses that were conducted many years ago contain data on the composition of flowback and produced waters, and noted it is difficult to obtain useful information from paper copies of incident reports. The Panel member noted that several companies who presented at a spring 2013 SPE conference on environmental impacts of hydraulic fracturing may have useful information that ORD could gather and assess. The Panel member suggested that EPA discuss what data are available for future analysis, and conduct a breakdown analysis on the available data. The Panel member also recommended that EPA's research could be strengthened if EPA included actual hydraulic fracturing industry information. Such information would include discussion on how hydraulic fracturing wells leak, what is meant by a spill, how valves that

connect to tanks may be leaking, and how pipe body and tank failures occur. The Panel member noted that such information would be helpful for the public's understanding of spills.

A Panel member asked whether ORD could adjust data input requirements for the databases it is using so that ORD can pull out meaningful reported data. Ms. Briskin responded that she was not sure this was a practical approach, and that there may not be sufficient time to make such changes. Ms. Briskin noted that in order to develop a December 2014 Report of Results, ORD will have to identify a cutoff timeframe for usable data.

Another Panel member commented that in situations where spills occur in pristine conditions and where past contamination may have occurred, it is difficult to analyze the chemicals in spill materials from both of these situations or types of spills. One Panel member commended EPA for trying to make this information publicly available. The Panel member commented that the U.S. Department of Energy's (DOE) National Energy Technology Laboratory website includes reports that provide interesting syntheses and many references that would be useful for ORD to consider. In addition, the Panel member commented that use of chloride as an indicator chemical may be difficult to assess since it might have other sources for its presence in the environment. The Panel member also noted that while nitrogen is an indicator of agricultural pollution and is also produced as waste from automobile use, it still is a useful indicator for hydraulic fracturing activities.

A Panel member suggested that since ORD collected data from 400 wells, it should assess data on all 400 wells rather than a smaller data subset on 50 wells. The Panel member further suggested that ORD consider expanding its well file review to the four case studies.

One Panel member commented that since there are multiple audiences for EPA's Progress Report and EPA's research reports, EPA should develop diagrams in addition to text that visualize points made in the text. Another Panel member commented that while EPA's spill database lacks granularity regarding what is a spill, the State of Pennsylvania website is specific on what information is needed for spills. A few Panel members noted that since many spills are in contained areas, a spill does not necessarily mean there has been a release to external groundwater, and suggested that EPA gather information on situations where this occurs.

One Panel member asked whether spill volumes that are under reportable quantities might be significant, concentrated spills. Ms. Briskin responded that this depends on the State where the spill occurred, and the material that is spilled. She noted that a spill of relatively pure material that has not been mixed with water yet would be more toxic than hydraulic fracturing flowback water that is mixed with water. The Panel member commented that it is important to know whether there are 1,000 or more of such unreported spills. The Panel member also noted that when a spill of flowback or produced water has entered the ground, EPA should understand whether that type of spill resulted in a loss of chemical.

A Panel member asked whether spill volumes vary significantly, and whether the type of geology where the spill occurs affects the volumes of the spill. Ms. Briskin responded that the amount of flowback water does depend on the type of geology, and that a spill of 5000 gallons of flowback water may have different impacts than a spill of three million gallons of flowback water.

One Panel member noted that the previous SAB review discussed flowback and produced water, and it is important for EPA to continue to keep clarifying these different waters. The Panel

member also noted that the public is keenly interested in data and analysis on the frequency of spills at hydraulic fracturing sites, and this is highly reported in the State of Pennsylvania. Ms. Briskin noted that ORD is gathering information on spills at hydraulic fracturing sites, and will consider this issue as ORD evaluates literature.

A Panel member asked whether data that EPA would be gathering from literature and other sources for its hydraulic fracturing research would be subjected to EPA's peer review processes. Ms. Briskin responded that EPA's peer review and quality assurance/quality control guidelines will be followed for data that EPA would be using for its hydraulic fracturing research. Ms. Briskin noted that EPA's hydraulic fracturing research is considered a Highly Influential Scientific Assessment (HISA), and that while the individual pieces of ORD's hydraulic fracturing research are not considered HISA, EPA's Peer Review Guidelines provide criteria for how EPA will conduct peer review on these pieces. Ms. Briskin noted that the majority of the peer review that is conducted on data that ORD gathers from literature is submitted through peer review journals for publication. Ms. Briskin also noted that where confidential business information (CBI) exists on any data that ORD will use in its hydraulic fracturing research, ORD's use of that data will meet EPA requirements for CBI.

A Panel member asked how ORD determined that the individual pieces of ORD's hydraulic fracturing research are not considered HISA. Ms. Briskin responded that ORD reviewed guidelines for determining what qualifies as a HISA. A Panel member requested a list of the reports that ORD would be sending for peer review. Ms. Briskin responded that there was no particular list at present, but estimated that approximately 20 individual pieces of ORD's hydraulic fracturing research would be submitted for peer review. She noted that ORD's 2014 Report of Results would contain a synthesis of the peer reviewed materials. A Panel member commented that it would be helpful if ORD kept the Panel informed as to what is being peer reviewed, and noted that ORD could brief the Panel on this rather than produce a lengthy report. The Panel member also noted that even if there are 20 individual research pieces submitted for peer review, the Panel may still provide comments on those individual research pieces.

One Panel member asked whether it was standard practice for ORD to conduct peer review on the individual pieces of its hydraulic fracturing research. Ms. Briskin responded that the SAB preferred that ORD conduct peer review on the individual pieces of its hydraulic fracturing research before ORD sent SAB the synthesis document for review. Mr. Thomas Brennan of the SAB Staff Office noted that it would be very difficult for the SAB to peer review over twenty separate documents.

Another Panel member asked whether ORD would exclude data that did not undergo peer review through a journal. Ms. Briskin responded that ORD will have to consider that question as it moves forward in its research.

Hearing no further comments from the Panel on Charge Question 9, Dr. Dzombak noted that any member of the public who would like to make clarifying comments near the end of the May 8, 2013 meeting should let DFO Edward Hanlon know by noon on May 8. The Designated Federal Officer recessed the meeting at 5:15 pm ET.

May 8, 2013

Dr. Dzombak welcomed everyone and requested that all members introduce themselves. Dr. Dzombak stated that the present effort of the Panel was a consultation and not an advisory effort, and that members of the Panel would be providing their individual expert written comments. Dr. Dzombak noted that Panel members have writing assignments, and requested that Panel members provide their individual written comments to DFO Edward Hanlon by May 21, 2013. He also noted that Panel members should not communicate with each other to develop written comments.

Dr. Dzombak also noted that during the May 7, 2013 public meeting, a few Panel members stated that they were “writers”. Dr. Dzombak clarified that these Panel members were referring to their individual expert writing assignments for the SAB Panel, and noted that Panel members were not writers of EPA’s Progress Report.

Responses to Charge Question 10: Assessing How Spills or Leaks May Impact Drinking Water Resources: *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.*

One Panel member commented that ORD stated that it did not have information on the concentration, volume and impacts associated with chemicals that are spilled or leaked, and noted that ORD should try to gather this information. The Panel member also noted that ORD should identify which spills are from flowback water. The Panel member recommended that ORD clarify whether the volumes of flowback water changed depending on the geology or regional location. The Panel member noted that a public commenter requested that ORD make the data and information that it analyzed for spills publicly available.

A few Panel members recommended that EPA assess more than two prospective case studies. One Panel member suggested that EPA develop a sampling plan that includes random sampling at more than one site. A Panel member recommended that EPA assess current practices by hydraulic fracturing owners and operators, and include case studies that do not consider containment. The Panel member suggested that EPA assess trends for this information. The Panel member also noted that since ORD’s spill analysis would be used to guide decision-makers, ORD should consider providing context on the spills and how hydraulic fracturing spills relate to other spills such as glycol or chemical spills.

Another Panel member commented that individual case studies are important and should be put into context. The Panel member suggested that ORD be as inclusive and creative as possible in gathering spill information, and noted that ORD should discuss how it would score or rank spill information in terms of relative importance (e.g., in occupational health and safety analyses, odor and taste provide some threshold information related to a compound that is useful to consider). The Panel member recommended that ORD develop matrices that include odor and taste threshold information, and form patterns about the relative importance and potential impacts of hydraulic fracturing spills. The Panel member also commented that EPA should clarify which chemicals are present or not present in hydraulic fracturing fluids. The Panel member expressed concern about the sheer volume of produced water that EPA reported in its Progress Report, and recommended that EPA conduct random sampling of this water in conjunction with other entities. The Panel member commented that EPA had an incomplete matrix from which it could statistically evaluate this data.

A Panel member noted that EPA should provide information on underlying soils and depth to groundwater for areas where spills occur in order to assess groundwater and surface water impacts. The Panel member noted it would be helpful if EPA screened chemicals based on toxicity, persistence and mobility in order to narrow down the chemicals of concern. The Panel member also noted that spill volume was important particularly if EPA was assessing which chemicals dissolve in water or are non-aqueous phase liquids. The Panel member also noted that the State of Colorado spill database provided useful information on causes of spills. The Panel member also noted it would be helpful if EPA gathered information on how chemicals move through the vadose zone. The Panel member stated that data may not exist on whether impacts occur from spills, and commented that information on secondary containment at well pads would be helpful. The Panel member recommended that EPA provide diagrams focused on management of fluids within storage impoundments, and provide specifications for the impoundments. The Panel member also recommended that EPA cross-check spill data with available groundwater and surface water quality data in the vicinity of the spills.

A few Panel members noted that since many spills are in contained areas, a report of a spill does not necessarily indicate that there has been a release to external groundwater, and recommended that EPA gather information on situations where this occurs.

One Panel member suggested that EPA gather actual exposure information and IRIS (Integrated Risk Information System) values on chemicals of national concern. Another Panel member recommended that EPA conduct statistical analysis to identify a fraction of well sites from which it would gather data. The Panel member suggested that EPA assess the frequency and size of spills, and note which spills were considered trivial. The Panel member also recommended that EPA should clarify the volumes of spills that have occurred, identify a de minimis spill amount that EPA would not assess, and clarify whether spills are 90% water. The Panel member suggested that EPA conduct Monte Carlo Analyses on its spill assessment. The Panel member commented that EPA has some reports of spills and major blowouts, and if sufficient data were available through these reports to allow EPA to gather a statistically representative sample, EPA should assess whether how the spill rates compare with spills for other industries. The Panel member also recommended that EPA conduct a trend analysis on the frequency of spills to determine whether spills are increasing or decreasing.

A Panel member noted that ideally, EPA should have pre- and post-spill monitoring data to assess the release, and commented that in most cases EPA may not have that information. The Panel member suggested that EPA identify the volume of spills, and commented that the extent to which EPA can use statistical methods directly is limited to the data in the databases. Regarding how to identify de minimus spill volumes, the Panel member suggested that one statistical approach would be that EPA focus on the size and frequency of spills (e.g., spills per month), and estimate the frequency of spills sorted by size of spills. The Panel member noted that the rate of spill was important, not the total number.

One Panel member noted that a 1989 publication by Mackay and Cherry [Mackay, D.M. and J.A. Cherry. Groundwater Contamination: Limits of Pump-and-Treat Remediation. *Environ. Sci. Technol.* 23(6): 630-636, 1989] assessed six spills across the United States, and investigated the relationship between the spill source and groundwater plume size. The Panel member noted that the publication discusses a spill in San Jose California of five billion liters of volatile organics, and also a trichloroethylene spill in Cape Cod of 1,500 liters that resulted in 40 billion liters of groundwater plume. The Panel member noted that the Cape Cod spill exemplified that small spills may be significant, and recommended that ORD not exclude small spills from its analysis.

One Panel member suggested that EPA clarify in its reports what is the extent of reporting, particularly for small spills, and whether small spills are unreported. Another Panel member commented that EPA's Progress Report should have provided information on modeling efforts that ORD would be conducting to make a connection of spills with human health. Such efforts should assess confounding factors, and sources of data such as health reports from hospitals near the area of the spill.

A Panel member asked how EPA used statistical sampling in its well file review to reduce the number of well data that it investigated from 25,000 wells to 350 wells. Ms. Briskin responded that ORD conducted a stratified sampling approach to reduce the number of wells it investigated. The Panel member responded that EPA reduced the number of wells too much, and suggested that EPA assess county well data information and merge that information with case study information.

One Panel member noted that EPA's Progress Report was not clear how EPA investigated the spill sites, and noted ATSDR's reports from spill sites might provide useful information to ORD on their reporting on spills. Ms. Briskin responded that ORD only assessed 2009-2010 spill data, and did not bias its sample towards only wells that had data. She noted that ORD identified wells to investigate through a random sampling approach, then asked well operators for their existing data from wells that were fractured during those years if such data were not already available in the databases.

A Panel member noted that the latency period for health effects is important since such effects may not be instantaneous. Another Panel member commented that ORD should consider the modeling it will conduct in its analysis before EPA collects additional data for its research.

One Panel member noted that EPA would be short sighted if it only focused on spills that reported a documented impact, and recommended that EPA consider whether there would be a potential impact at some scale at some time, and consider whether there should be a presumption of potential impact through use of scenario analysis.

A Panel member requested information on how well-file review data were collected by ORD, and noted that even a small operator may have established procedures for how it constructed and operated its wells. Ms. Briskin responded that ORD's well-file review was not restricted to companies with a certain minimum number of wells. She noted that ORD collected well data from small, medium and large companies.

EPA Technical Presentation on Wastewater Treatment and Waste Disposal Water Phase of the Hydraulic Fracturing Water Cycle

Dr. Christopher Impellitteri of EPA ORD presented PowerPoint slides¹² on ORD's research on this phase of the hydraulic fracturing water cycle; the slides were provided on the meeting website. Regarding the disposal well indicated on the right side of slide 1, he noted that underground injection is not covered in this part of ORD's research study. He also noted that ORD lumped flowback and other water into the wastewater definition. He noted that there has been rapid change in this industry, since there were only four hydraulic fracturing wastewater treatment facilities three or four years ago, and now that situation has changed. Regarding slide 2, he noted that Charge Question 11 was not addressing analytical methodology. He commented that ORD sought information from the Panel members on other chemicals that ORD should be considering. He stated that there is a long list of analytes for ORD to consider, and that some top

priorities are TDS, bromide, radionuclides, gases and organics. Regarding slide 5, he commented that the two green bullets focused on treatability of the chemicals.

Regarding slide 5, Dr. Impellitteri noted that the State of Pennsylvania has set a 500 ug/l requirement for brominated discharges, and that the State would be releasing a report in a few months to specify these releases. He commented there is possibility of brominated discharges to rivers. Regarding slide 6, Dr. Impellitteri noted that treatment technologies are currently undergoing significant change, and noted that industry is working to provide a 'tailor-made water' for particular applications. He noted that while EPA is considering various chemicals for study in its treatability studies, there were significant challenges associated with developing analytical methods for high salt matrices.

Regarding slide 7, Dr. Impellitteri noted that sample collection will occur at two or three sites. Regarding slide 8, Dr. Impellitteri noted that over the past year, POTWs were becoming part of the picture for treatment of these wastewaters. He noted that commercial facilities will pretreat discharge, then send the pretreated wastewaters to POTWs for their final treatment. He noted that this assessment was considering the effects of these wastewaters on biological processes, and on fate/transport through biological processes. He stated that ORD was using a synthetic wastewater to blend the hydraulic fracturing wastewater, and commented that depending on the location in the United States, wastewater characteristics vary significantly.

Regarding slide 9, Dr. Impellitteri noted that the wastewaters that were being used were very salty, and that some waters had 100,000 mg/l for TDS. Regarding slide 11, Dr. Impellitteri noted that some operators are recycling 50% or even 100% of their treated wastewaters, with changes of these percentages depending on the time of year. He stated that there is high demand for these treated wastewaters some portions of the year, and noted that some wastewaters are discharged to surface water and some treated brine waters undergo underground injection. He noted there are beneficial use issues associated with wastewaters from hydraulic fracturing operations. He noted that in Pennsylvania, there are rural roads and the availability of discharges from these facilities can be difficult. He also noted that in Texas, discharges are often underground but that there is a trending change towards surface discharges.

Regarding slide 14, Dr. Impellitteri noted that the State of Texas rewrote their laws for sharing waters used in the process of hydraulic fracturing. During the discussion of slide 14, ORD staff distributed to the Panel members a list of analytes¹³ that ORD was assessing as part of its wastewater treatment and waste disposal research.

A Panel member asked how ORD was quantifying data that would be used in its research. Dr. Impellitteri responded that ORD's most significant issue on this topic was identifying the amount of change that is occurring. He noted that two treatment facilities provide a high level of pretreatment, and ORD was seeking information on what is going in and out of these facilities. A Panel member asked what pretreatment occurred on the hydraulic fracturing wastewaters before those wastewaters reached POTWs. Dr. Impellitteri responded that there is significant variation in pretreatment, and noted that a mobile, package treatment unit on a trailer was frequently used by hydraulic fracturing operators. He noted that POTWs that have an economic advantage include those who can tailor their treatment process to allow the POTW to accept these wastewaters. He also noted that treated water with lower TDS can potentially be resold as reused wastewater. He further noted that some hydraulic fracturing wastewaters may not be able to meet POTW pretreatment or capacity issues.

A Panel member asked how treatment reactors being studied in the research were being spiked. Dr. Impellitteri responded that for a Pennsylvania facility, ORD is checking how salt is affecting the POTW's biological reactors, and assessing calculated blending rates for acceptable levels. The Panel member noted there exists a significant amount of published literature on this topic. The Panel member asked whether ORD was assessing full scale treatability of hydraulic fracturing wastewaters. Dr. Impellitteri responded that ORD was not conducting full scale analyses. He also commented that ORD was assessing the treatability of disinfection byproducts (DBP) that are generated during hydraulic fracturing wastewater treatment. A Panel member responded that a broad DBP model could not be generated, and that ORD must look at individual treatment systems to identify treatability of DBP.

A Panel member asked when ORD's study of treatment of bromides within Pennsylvania would be released. Dr. Impellitteri responded that a final report was being drafted and should be released within one to two months. He also noted that the Ohio River Valley Water Sanitation Commission (ORSANCO) has completed a study from 17 sampling sites for bromide treatment. He noted that while the study did not provide data on the effects of bromine on drinking water treatment, there is significant interest in bromide and how to manage it.

A Panel member asked what issues arise regarding reuse of brine water. Dr. Impellitteri responded that POTWs had difficulty treating TDS, managing scale and formation from calcium and barium, and addressing bacteria issues associated with acceptance of hydraulic fracturing brine wastewaters for treatment. Another Panel member commented that the State of Pennsylvania recently changed its discharge requirements relevant to hydraulic fracturing information, and asked whether ORD had information or tables noting which States have such discharge requirements. Dr. Impellitteri responded that ORD did not have that information but could generate it.

A Panel member asked whether ORD was assessing injection wells. Dr. Impellitteri responded that underground injection (UIC) wells were outside the scope of EPA's research study, but commented that such wells are a significant sink for hydraulic fracturing wastewater. Ms. Briskin noted that UIC wells are not being studied within this ORD research for reasons described in EPA's Study Plan for assessing the potential impacts of hydraulic fracturing on drinking water resources. She noted that ORD will be considering whether hydraulic fracturing wastewater treatment practices are driven by requirements for use of UIC wells.

Responses to Charge Question 11: Wastewater Treatment and Waste Disposal Chemicals:

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

A Panel member commented that the list of chemicals that go into hydraulic fracturing wells that is included in Appendix A of EPA's Progress Report has changed over the years, and that it was difficult to identify which compounds, chemical mixtures, DBPs, precursors to DBPs, and carcinogens from Appendix A were most significant. The Panel member noted that secondary nitrosating agents, halo nitromethanes, trihalomethanes, perfluorinated compounds used as surfactants and lubricants, perfluorooctanoic acid, perfluorooctanesulfonic acid, and halogenated compounds may be of concern and EPA should consider including them as chemicals of interest. The Panel member noted that these chemicals have only recently been monitored and analyzed in wastewaters. The Panel member noted that as hydraulic fracturing wastewaters arrive at POTWs and industrial wastewater treatment plants, common disinfectants at these plants may react with some of these new compounds in hydraulic fracturing wastewater. The Panel member noted that

there is a very long list of mixtures that may cause catalyst reactions that may affect formation of new compounds, and that some newer mixtures are being patented due to their ability to be injected.

A Panel member noted that EPA should consider gathering wastewater from industries such as the lignin, pulp/paper, and petrochemical manufacturing industries, in order to assess how hydraulic fracturing wastewaters can be blended at POTW plants.

Another Panel member noted that it was uncertain where all hydraulic fracturing wastewater goes, and that that fate information would be useful in identifying which chemicals are important. The Panel member noted that if particulates are released to POTWs, it was important to gather information on the characteristics and fate of the solids (e.g., whether particulates from the industry are contributing to final effluent turbidity). The Panel member commented that bromides are an issue and may have health effects or odor problems. The Panel member suggested that other contaminants or parameters were an issue in hydraulic fracturing wastewater and should be monitored, including TDS, temperature, alkalinity, dissolved silicates, phosphates, chlorates, mercury, nitrosamines, ammonia, disinfection byproducts, dissolved organic carbon, ultraviolet absorbants, turbidity, oxygen demand, microbial presence, species of iron, and nutrient concentration. The Panel member noted there is significant literature available on these compounds and issues.

A Panel member asked whether EPA was planning to assess only one POTW in the research. Dr. Impellitteri responded that this is a monitoring design issue, and EPA was limited on how many samples that could be collected for this part of ORD's research. The Panel member asked whether it was less expensive and more productive to take a limited number of samples at a number of facilities, or a lot of data from a few facilities. The Panel member also noted that a large amount of pH data are available. Dr. Impellitteri responded that ORD would compare the field data being collected to other available data (e.g., from the State of Pennsylvania, or from the oil and gas industry). Dr. Impellitteri also noted that since ORD's standards for quality assurance for data that it collects are high, it is difficult for ORD to gather and use data from secondary sources.

Another Panel member suggested that instead of expanding its list of compounds, ORD could use indicator chemicals that indicate whether treatment removal is occurring and which compounds are most toxic. The Panel member questioned whether it was helpful for ORD to prepare a large list of chemicals that can be measured using techniques like gas chromatography–mass spectrometry, since it may not be effective to sample and analyze all chemicals on such a list. The Panel member also suggested that it would be helpful to add polyacrylamide to the list, since wells that use this chemical and operate at higher temperatures in deep formations may break the chemical down to acrylamide, which is difficult to remove from treatment processes. Dr. Impellitteri responded that ORD would consider adding these chemicals to its list, and noted that methylene glycols also have similar properties and characteristics. He commented that ORD's Las Vegas research laboratory methods development scientists had placed the acrylamides and glycols as high priority for analytical research in the study.

One Panel member commented that perhaps ORD could consider using the EPA Superfund Program's framework for use of data after considering data quality objectives. Dr. Impellitteri responded that ORD's main challenge was to identify how it would narrow down the extensive list of organic compounds so that it could focus on perhaps 10% of the entire list of chemicals. The Panel member suggested that ORD develop a decision framework to guide how ORD would

narrow down the chemicals.

Another Panel member suggested that ORD include the major anions and cations in the list. One Panel member noted that the technology has evolved on what EPA can measure. Another Panel member suggested that EPA review databases such as state and oil/gas company databases to identify the most common analytes monitored.

One Panel member suggested that EPA clarify its discussion on which source apportionment modeling it would use to assess sources of contamination. Dr. Impellitteri responded that ORD's source apportionment modeling was considering data collected above and below point sources, that ORD was looking to identify particular markers and different potential sources through this modeling, and that potential sources can include coal-fired plants. One Panel member suggested that methane be included in the list of analytes that ORD would include in its commercial wastewater treatment and DBP research studies. The Panel member commented that USGS is currently investigating analytical methods for methane, and suggested that ORD consider alternative methods for analyzing volatile and semi-volatile compounds.

Responses to Charge Question 12: Trends in Wastewater Management that May Affect Hydraulic Fracturing Wastewater: *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?*

A Panel member commented that water reuse and recycling practices are changing across the world. The Panel member noted that drought in the United States is a significant issue, and the price of water is rising. The Panel member also noted that wastewater is being considered for various uses, depending on availability, and that there is increased use of poor quality source waters such as waters with elevated TDS. The Panel member noted that hydraulic fracturing operators are making changes in formulations to improve performance of hydraulic fracturing operations, tailored to regional conditions. The Panel member commented that such formulations may have reduced toxicity at lower cost, and result in increasingly concentrated wastestreams. The Panel member noted that such formulations may result in a salt buildup over time, and that some compounds are precipitating out of the wastewaters.

The Panel member commented that there are different processes involved in treating wastewater from hydraulic fracturing operations. The Panel member noted that there are improvements in treatment technologies for wastewater from hydraulic fracturing operations, that some of the newer processes include electrodialysis and increased use of membrane treatment technologies with corresponding reductions in treatment costs. The Panel member commented that it may be cost effective to evaporate or crystallize concentrated brine. The Panel member noted that some operations were reusing all produced water, and suggested that ORD refer to the *Produced Water Journal* for more information on the topic. The Panel member commented that polybrominated biphenyls (BPPs), iodated BPPs, and precursors of nitrosamines were a major concern in wastewater from hydraulic fracturing operations. The Panel member noted that while most conventional treatment processes could not treat BPPs, treatment options are available for BPPs.

A Panel member commented that EPA's Progress Report should provide a timeline for activities within Chapter 5, and provide data in Chapter 7 (e.g., on bromide). The Panel member suggested that ORD screen the list of chemicals in hydraulic fracturing wastewater to identify chemicals known to have an effect on biological treatment. The Panel member suggested that ORD consider use of wastewater management modeling to assess hydraulic fracturing water

management and treatment options within the watersheds in Pennsylvania and Colorado being studied, and that ORD use a geographic information system to identify locations of wastewater treatment facilities (WWTFs).

The Panel member suggested that ORD consider pathogen and microbial risks in its research, and whether treatment technologies are available for antibiotics that may be in hydraulic fracturing wastewaters. The Panel member noted that ORD should understand the frequency and duration of “slugs” of hydraulic fracturing flowback and produced water into WWTFs, and that ORD should consider how slugs affect the mean stream flow calculations used in ORD’s research. The Panel member also suggested that ORD consider how in-home water saving devices affect WWTFs accepting hydraulic fracturing flowback and produced water.

The Panel member recommended that ORD consider the impact that nitrogen and total phosphorous have on WWTFs accepting hydraulic fracturing flowback and produced water. The Panel member also suggested that ORD consider whether the increasing trends for reuse of water for a variety of purposes impacts the treatability of hydraulic fracturing wastewaters at WWTFs. The Panel member noted there is a trend towards use of membrane treatment technologies for the treatment of hydraulic fracturing wastewaters, and suggested that ORD assess whether advanced oxidation processes such as coupled ultraviolet-peroxide and ozone-peroxide treatment should be considered for treating hydraulic fracturing wastewaters that contain a large amount of organics. The Panel member recommended that ORD consider whether the uses of residual biosolids for land application and composting were affected by the discharge of hydraulic fracturing wastewaters to WWTFs.

The Panel member noted that ORD should clarify its discussion on membrane pretreatment on page 104 of EPA’s Progress Report, and assess the use of membrane fouling agents such as barium sulfate in its analysis. The Panel member also noted that ORD’s discussion on the use of bench, pilot and full scale studies should include details on the concentrations of wastewater that would be studied. The Panel member suggested that ORD consider use of simple jar tests to provide information on treatability of hydraulic fracturing wastewaters.

A Panel member commented that ORD should consider the significant energy required to be spent by WWTFs to treat the various organic materials and complex mixtures within hydraulic fracturing wastewaters. The Panel member commented that ORD should assess the use of onsite membrane process package units to treat hydraulic fracturing wastewaters, with consideration given to disposal of concentrated materials, and pretreatment to prevent fouling on the membranes.

Another Panel member suggested that ORD should distinguish the primary constituents and sources of variable TDS in hydraulic fracturing wastewaters, and noted that high TDS in such wastewaters may be due to sodium chloride.

A Panel member asked whether there is a trend towards use of commercial WWTFs for treatment of hydraulic fracturing wastewaters, and if so, whether that would make it more difficult for ORD to assess contributions from hydraulic fracturing wastewaters to those facilities. Dr. Impellitteri responded that in general, use of mobile treatment systems to treat hydraulic fracturing wastewaters tended to be dedicated to treating only hydraulic fracturing wastewaters. He noted that centralized WWTFs tend to accept different industrial wastes and tend not to be dedicated to treating only hydraulic fracturing wastewaters. He also noted that hydraulic fracturing wastewaters were the primary influent into most WWTFs that accepted

hydraulic fracturing wastewaters. One Panel member suggested that ORD consider green chemistry when identifying preferred treatment technologies for hydraulic fracturing wastewaters.

Another Panel member commented that ORD should consider trends for the composition and treatment of hydraulic fracturing wastewaters across all basins within the different States where hydraulic fracturing occurs (e.g., in Pennsylvania, Ohio, Texas, Colorado, the Dakotas, and elsewhere). Dr. Impellitteri responded that ORD would assess this issue through its literature review process, and noted that processes that could treat the Marcellus shale hydraulic fracturing wastewaters should be capable of treating hydraulic fracturing wastewaters from other formations. He stated that Marcellus shale wastewaters had the highest levels of brine water across the nation.

Another Panel member commented that ORD should assess why water reuse of treated hydraulic fracturing wastewaters is occurring in water-rich northeastern United States, whereas hydraulic fracturing operations in Texas frequently use fresh water. Dr. Impellitteri responded that ORD would assess this issue, and noted that this was partly due to contracts that have been signed for use of such waters and certain State regulations that apply for water reuse.

Another Panel member commented that ORD should develop tables that indicate the types and trends for treatment of hydraulic fracturing wastewaters and the uses of such treated waters on a state by state basis, and describe what drives such uses. The Panel member suggested that ORD consider comparing such a trend analysis with similar trends for biosolid production and agricultural use.

EPA Technical Presentation on Well Injection Phase of the Hydraulic Fracturing Water Cycle

Ms. Jeanne Briskin of EPA ORD presented PowerPoint slides¹⁴ on ORD's research on this phase of the hydraulic fracturing water cycle; the slides were provided on the meeting website. Dr. Stephen Kraemer, Dr. George Moridis of Lawrence Berkeley National Laboratory (LBNL), and Mr. Nathan Wisner assisted Ms. Briskin during the presentation and question/answer period.

Regarding slide 1 of her presentation, Ms. Briskin noted that this phase of the hydraulic fracturing water cycle focuses on subsurface migration, and the effects of casing and cementing, other nearby potential pathways, faults and fractures, nearby abandoned wells and other factors. Regarding slide 2, Ms. Briskin commented that 75% of drill rigs in the United States are for oil drilling. She noted that wells for drinking water and petroleum may be drilled into the same formation, and that EPA was conducting a modeling and well file review effort to assess this.

Regarding slide 4, Ms. Briskin stated that ORD was collaborating with the Lawrence Berkeley National Laboratory, and was conducting a literature review, interviews with experts, gathering empirical data, and running two types of models to assess contaminant migration. She noted that ORD interviewed Drs. Stephen A. Holditch of Texas A&M University, Mark Zoback of Stanford University, and Chad Landis of the University of Texas. She commented that ORD was assessing four scenarios in its analysis and checking whether induced fractures are affected by the four scenarios. She also noted that ORD's research should address questions such as what factors affect migration if there is a pathway. A Panel member noted that the slide indicates that EPA is assessing the geophysical likelihood of a pathway, and commented that when assessing likelihood, Monte Carlo simulations should be used to assess all possible options. Dr. Moridis

responded that while the Lawrence Berkeley National Laboratory can run a complex model using a half million equations in a few hours, due to limits on budget and availability of data, his Laboratory could not apply Monte Carlo simulations at this stage. He also noted that in addition to interviews with the three experts noted by Ms. Briskin, additional experts at Andarko Petroleum Corporation, Chevron, Chesapeake Energy Corporation, and another oil and gas drilling company were interviewed.

Regarding slide 6, Ms. Briskin commented that the vertical distances between the fracture zone and the aquifer range between 100-300 meters, to depth of 1,500 meters.

Regarding slide 7, Ms. Briskin commented that the LBNL supercomputer was being used for assessing fate/transport issues. A Panel member noted that the slide infers that coal bed methane, shale gas and oil drilling operations may all be occurring in the same basin, and noted that this may not be the case. The Panel member suggested that ORD clarify the differences between drilling operations for coal bed methane, shale gas and oil in its written materials.

Regarding slide 10, Ms. Briskin commented that data from 25,000 well files were considered, and that ORD requested information on 350 wells that had been hydraulically fractured. She noted that ORD ensured that the wells that were assessed as part of this review were in different geographic locations. A Panel member noted that the report states that ORD was assessing data from 350 wells, and asked whether the actual number of wells that ORD was assessing was less than 350. Ms. Briskin responded that although ORD requested information on 350 wells, a few of these wells were indicated to have not actually been fractured, and the actual number of well files that ORD assessed is under 350.

Regarding slide 14, Ms. Briskin noted that ORD was considering whether to assess both oil and gas production types. She stated that the American Petroleum Institute recommended that a cement bond index of 80% was a good cement bond. Regarding zones and degree of cement, she noted that ORD was assessing where cement exists (e.g., from toe of well and up), and what is the quality of cement. A Panel member noted that while every state requires cementing and surface casing for wells, Figure 14 and other figures did not depict surface casing. Ms. Briskin responded that Figure 14 was a simplified figure and was not intended to depict the type of well that is being modeled. She also noted that ORD was assessing the depth of surface casing. Dr. Moridis noted that the modeling effort could be adjusted depending on the description of the wells for the modeling. He also noted that in most cases surface discharge issues do not reach the subsurface.

Regarding slide 14, several Panel members suggested that ORD provide a better description and generate better figures for how these wells were modeled, and noted that the figures should reflect current hydraulic fracturing practices. A Panel member noted that ORD should request information describing the type and quality of cement being used, and how it was laid. The Panel member suggested that ORD spend time with well drilling engineers so that it receives a higher quality answer. The Panel member suggested that ORD should gather information on current practices in the design and construction of hydraulic fracturing wells. The Panel member noted that ORD could gather data on background geologic and petrochemical analysis, monitoring data on the well annulus such as for pressure differences before and after hydraulic fracturing operations, data that compare well construction and installation information for wells that are within/on the same hydraulic fracturing pad, and data on microseismic events associated with hydraulic fracturing. Ms. Briskin responded that ORD was considering this, and noted that ORD was assessing whether cement bond logs could provide information on potential hydraulic

fracturing impacts. Another Panel member recommended that in addition to cement bond logs, ORD should consider whether the cement is Type A or another type of cement. Ms. Briskin responded that ORD was considering this if the company provided that information.

Regarding slide 15, Ms. Briskin noted that the intermediate interval of the well may or may not have cement. She noted that for less than fully cemented wells, ORD was assessing the extent of wellbore cementing. Regarding slide 16, a Panel member asked whether ORD requested monitoring data from the operator. Ms. Briskin responded that ORD requested such data, as well as data on hydraulic fracturing operations, pressure testing, seismic data, and other data.

A Panel member asked ORD to describe cooperation of service companies in its research. Ms. Briskin noted that ORD sent letters to nine service companies and nine oil and gas companies, and that all of these companies sent letter responses with well-file data. Another Panel member asked whether ORD coordinated with DOE, USGS, and other countries such as England and Canada, in developing its research. Ms. Briskin responded that ORD coordinated with the agencies and conducted literature searches to gather appropriate information and data. She noted that LBNL is coordinating the development of ORD's modeling.

One Panel member noted that the Marcellus Shale formation is widely dispersed and may not be generalized. The Panel member noted that in some geographic locations where hydraulic fracturing within the Marcellus Shale formation was occurring, oil and coal bed methane drilling occurs near ground surfaces and abandoned wells may be prevalent. The Panel member noted that this may not be the case in other locations where hydraulic fracturing within the Marcellus Shale formation was occurring.

A Panel member requested more detailed information on ORD's modeling effort. The Panel member asked whether the modeling was steady state or transient, whether it was three dimensional, and whether the modeling varied depending on brine and other chemistry. Dr. Moridis responded that the modeling was transient and three dimensional. He noted there were no steady state parameters in the model. He also noted that the final report and peer review publications that ORD would release will describe the modeling that was conducted.

The Panel member asked whether the fracture network of the modeling was handled as discrete or combined fractures. Dr. Moridis responded that while the modeling handled hydraulically-influenced fractures as discrete fractures, the modeling accounted for native fractures as combined fractures. The Panel member asked whether the LBNL modeling group was changing the modeling by model layer. Dr. Moridis responded that the LBNL group was making these changes, and was gathering information from literature on this. He noted there were limited data that supported this, and that much of the usable information is confidential business information. He also noted that LBNL was conducting a sensitivity analysis on a range of modeling values and mechanical properties as part of the modeling effort.

The Panel member noted that while it was useful for ORD to interview experts from different petroleum universities, ORD did not interview experts from the eastern United States. Dr. Moridis responded that LBNL used Marcellus shale scenarios only as a baseline, and that LBNL also reviewed data on the Hainsville formation as well. He commented that the formations reviewed by LBNL covered a range of all shales in the United States. A Panel member responded that since all shale formations are different, variations of different shale basins should be incorporated into EPA's scenario analysis. The Panel member noted that even within one shale, large varieties occur, and therefore one model execution could thus not be applied to

another execution.

The Panel member further noted that it is critical for EPA to consider the stress state of the formation in its scenario analysis, and assess how differences between the horizontal stresses affect propagation of fractures. The Panel member also noted that EPA should analyze well-file data to gather and use data on stress conditions for each basin within the modeling scenarios. The Panel member noted that rock temperatures in drilling zones differ, and result in differences in well chemistry. A Panel member asked whether ORD asked operators for borehole breakout data on minimum/maximum horizontal stress. Mr. Wisner responded that in a few cases, ORD received data on geomechanical properties from geomechanical logs that were taken. Dr. Moridis commented that he was not sure whether data on minimum/maximum horizontal stress using calipers was gathered for the modeling analysis, and noted that if such data were not gathered, it might be useful to gather that data.

A Panel member asked whether ORD streamlined its modeling analysis, and requested whether the grid range that LBNL used within the modeling was the same as the modeling used to support prior analyses on the potential environmental impacts associated with drilling for coal bed methane (CBM). Dr. Moridis responded that LBNL developed three dimensional modeling grids over a several day period, and noted that setting up the grid was the most time consuming part of its modeling work.

A Panel member asked whether EPA's modeling assessed well completion and differentiated between CBM, shale, and tight gas. Ms. Briskin responded that while EPA's modeling was simplified, the well-file review assessed whether the wells were vertical or horizontal. Mr. Wisner responded that EPA gathered data on well plugs and sleeves during well file review. Dr. Moridis responded that the modeling scenarios included these analyses, and that EPA's modeling assessed well completions both with and without cement. He noted that the modeling team first conducted a preliminary evaluation of issues, and asked the experts who were interviewed which scenarios were likely to occur.

One Panel member asked whether the TOUGH modeling code that was applied in the modeling effort used verified data. Dr. Moridis responded that LBNL's use of the geomechanical modules included a validation process step, where the modeling staff first checked literature and then checked laboratory results, and utilized field study information where available. He noted that while the models are robust, they are not field verified. He commented that the modeling staff coordinated with other LBNL staff to gather defense-based fracturing data, and that the staff compared its modeling results to other key studies conducted at LBNL. Dr. Moridis noted that the LBNL group was using the 'flat 3D code' to assess geomechanics of fault formation from fracturing; he noted this code was limited to formation of fractures, and not propagation of fractures. He also noted this code can simulate evolution of fracturing over tens of years. Dr. Kraemer noted that ORD recognizes that there would be great value in conducting site-specific studies on its models, and was hoping that the prospective studies would gather data for such analysis.

A Panel member noted that ORD is subdividing the problem that is being assessed through modeling into components, and was simulating the various components using different modeling codes. The Panel member noted that it is unclear how the model applied the single gas phase flow code. Dr. Moridis responded that the TOUGH modeling incorporated a variety of modeling codes, including a water gas code. He commented that there is no single gas module within the water gas code that was applied. He noted that there are two main modules for this water gas

code: one on water and gas (to assess rise of gas in system), and the other on contaminant transport (to assess oil, gases, solutes, and complex scenarios).

A Panel member asked whether the modeling simulated composition and recovery of flow. Dr. Moridis responded that the modeling assesses non-isothermal fractionalization of water. One Panel member asked whether non-Newtonian solutions were being modeled. Dr. Moridis responded that the models have the capability of assessing non-Newtonian solutions, but that the limited budget requires use of Sweetwater only.

A Panel member asked whether grid resolution was occurring with the modeling, since the modeled systems have instabilities. Dr. Moridis responded that LBNL was using the smallest possible grid to get the best result. He also noted that model runs immediately indicate whether a grid problem exists, and that approximately 20% of the modeling time was spent on grid issues.

A Panel member commented that some fractures are treated discretely, while other fractures are propagated, and asked how the LBNL group approached the changes in permeability of fracture formation. Dr. Moridis responded that there were no constant scenarios in the models. He noted that when simulating individual fractures, the aperture is changing constantly, and that the main model being used does assess changing permeabilities. He also noted that permeability and porosity change according to the stress system, and that stress affects permeability and vice versa. He stated that the selected model notes changes in the system except for changes in porosities and permeabilities.

One Panel member noted that data has changed since 2009 and 2010, and asked whether EPA was interacting with states and other federal agencies to gather information on the mechanical integrity of wells. Ms. Briskin noted ORD took a snapshot of what occurred from 2009-2010. She noted that the data that will be released may indicate situations where mechanical integrity may not have occurred in wells. She also noted that ORD was coordinating with agencies to understand their requirements, but that ORD was not undertaking a full review of those regulations.

A Panel member asked whether ORD was modeling fractures, wastewater flow, and mechanical characteristics, tracking volumes of water, and developing sorption isotherms. Dr. Moridis responded that the model tracked solutes including the range of those in heavy brines that affect density of water. He noted that kinetic sorption scenarios can be described if relevant parameter values can be determined. The Panel member asked whether ORD had sorption coefficient data, as well as information on temperature and pressure. Dr. Moridis responded that for the short term, worst case assumptions of no sorption would be used. The Panel member noted that ORD should consider gathering data to develop sorption isotherms.

Responses to Charge Question 7: Subsurface Fluid Migration Scenarios: *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) of EPA's Progress Report.*

A Panel member expressed appreciation to EPA that it is conducting and publishing its complex modeling effort. The Panel member noted that as indicated in Table 26 of EPA's Progress Report, it is important to assess both the effectiveness of current practices in containing releases before, during and after hydraulic fracturing, and geologic features that may affect such releases. The Panel member noted that other data may be available and useful. For example, there are 15

Class 1 Injection Wells in Ohio that have various test data available that could be assessed, including mechanical integrity tests. These data should be in the EPA regional office. Also, carbon sequestration wells in the midwest United States have generated data on pressure gradients and joint studies; DOE offices in Ohio and West Virginia have data on these wells.

The Panel member suggested that ORD revise the figure on page 64 of EPA's Progress Report so that it does not mislead the public. The Panel member suggested that ORD enlarge this figure and show surface casing on the figure. The Panel member also noted that Figure 15 incorrectly depicted the appearance of fractures and projected a scenario that is very unlikely to occur. The Panel member stated that fractures do not look nor move like an aorta that carries blood. The Panel member suggested that instead of an aorta, EPA should show a fracture path. The Panel member also noted that fractures come and go, and that gas moves up joints. The Panel member suggested that EPA should show outcrop photographs in its reports. The Panel member could provide borehole photographs to EPA if requested such photographs.

The Panel member noted that every scenario in Figure 16 and 17 appeared to indicate an upward hydraulic gradient. Dr. Moridis responded that the modeled system is static and bounded, and noted that the shale model boundary does not need to extend far laterally nor extend vertically to the land surface and atmosphere. The Panel member noted that the modeling should not be limited to upward gradient scenarios, since many case studies and modeling efforts show downward gradients. The Panel member commented that if downward scenarios were not used in EPA's simulations, the results could be misinterpreted.

The Panel member suggested that it was necessary for EPA to represent the natural flow system properly, qualify its model, and present graphics accurately. The Panel member noted that numerical tracker particles in shallow groundwater flow cells flow to streams from both sides of streams. The Panel member noted that a deeper tracker particle may flow under shallow streams and head to nearby rivers.

A few Panel members suggested that ORD avoid developing an unreasonably confident opinion on what is understood in the subsurface. A Panel member noted that such unreasonable confidence also occurred in the Superfund program, in which the subsurface was often mistakenly considered to be homogenous. The Panel member noted that ORD's hydraulic fracturing research modeling involves three types of fluid phase flow, utilizes dozens of model components, and has highly uncertain geochemistry, lithologies, and other properties that need to be factored into the modeling. The Panel member commented that the model represents the best science available, but ORD should acknowledge these uncertainties. The Panel member noted that statements in EPA's Progress Report such as 'we understand the geomechanics of this system' are not accurate, since ORD has not simulated any scenarios with certainty. The Panel member recommended that ORD address and build in uncertainty analysis as much as feasible into the modeling, and diligently work to ferret out available data. The Panel member also suggested that ORD seek out data on critical dominant parameters, such as tensions between interfaces, to reduce uncertainties. Another Panel member suggested that although LBNL is a world class modeling organization, ORD consider incorporating additional peer review into its modeling analysis to review and assess anticipated outputs of the modeling.

One Panel member commented that while ORD's modeling effort is a framework that is running ahead of the data, there is no easy way to address this dilemma. The Panel member stated that while ORD's work is advancing the science on assessing this problem and will lead to good research articles, given the uncertainties, ORD should recognize that its modeling effort cannot

be used as a decision-making tool at this time. Dr. Moridis agreed with Panel member comments concerning modeling uncertainties, and noted that unlike contaminant transport, the range of geomechanical properties indicated in the data is very constrained. He stated that ORD can therefore define limits of the modeling, and could be more confident in defining worst case scenarios.

A Panel member asked whether ORD considered incorporating Mr. Kevin Fisher's work on microseismics into the modeling work. The Panel member noted that Fisher's publications assessed shallow and deep microseismic properties at depth, noting that such properties change up the drill hole. The Panel member asked whether fractures that reach shallow groundwater become horizontal. Dr. Moridis responded that while the current version of the geomechanics modeling code can address seismic and microseismic issues including prediction of microseismic events resulting from hydraulic fracturing, the model does not assess the degree of complexity noted by the Panel member.

A Panel member asked whether data from geothermal energy development would assist ORD's modeling effort. Dr. Moridis responded that while such data would probably not provide useful information since different types of fractures are developed in geothermal energy development, he would consider the utility of using such data if it were available.

One Panel member recommended that EPA improve the clarity of its presentation and description of its modeling, and suggested that ORD add appendices to its reports that identify and describe all parameters used in this model, a prioritization process that identifies the key parameters within the model (e.g., the top ten 'drivers' of the model), and initial conditions for use of these parameters, databases that can be used to support the model. A few Panel members recommended that ORD identify the most critical data needs to support the model, since such information would help the public understand what data is needed to fill data gaps in the model. Dr. Kraemer responded that EPA's Progress Report provided a summary of parameters that needs to be populated in the modeling runs, and noted it would be helpful if there were a link between data needs and the figures within EPA's Progress Report. Ms. Briskin responded that ORD struggled with how to present information to the wide range of audience who reviewed EPA's Progress Report, and noted that ORD strived to describe the importance of the ongoing research in a clear and understandable manner for the general public audience. Dr. Moridis responded that the presentation of research results in journals will be very complex, and it is important and difficult to simplify such complex results so that they are understandable in communications with the general public.

A Panel member noted that the general public wants to be a stakeholder in this analysis, and is able to understand this complex information. The Panel member suggested that ORD consider reviewing articles published in *Environmental Health Perspectives* on transportation maps for moving nuclear waste, since these publications were very helpful in conveying complex ideas to the general public.

Another Panel member noted that it was appropriate for ORD to assess realistic worst case scenarios. The Panel member recommended that ORD's lifecycle analysis should assess whether casings corrode and whether casings fill up with formation water and contaminate other systems. The Panel member noted that the State of Kansas has about one half million exploratory wells, and approximately 10,000 of these wells are plugged each year. The Panel member noted that water moves up these deep open holes in shale areas during hydraulic fracturing, and suggested that ORD's modeling scenarios should assess this potential release.

Another Panel member noted that the public is interested in worst case scenarios, and that in Pennsylvania, there are any thousands of old and unidentified wells. Dr. Moridis responded that some States have strict regulatory requirements for abandoned wells. He commented that generally, abandonment of exploratory holes is not an issue with potential releases, but noted that ORD's workshops have identified that significant corrosion occurs in shale oil wells that have declined over 2.5 years of production.

A Panel member noted that since there is a limited data set that supports its modeling, ORD should compare its modeling results against case study modeling of what occurs in Kansas and Oklahoma. Dr. Kraemer responded that such case study modeling could potentially help populate ORD's model.

A Panel member complimented Dr. Moridis and his LBNL team and EPA for reaching out to other agencies for this research, and noted that EPA identified the correct group to do this modeling work. The Panel member noted that there is a need for well-file data, and recommended that the geomechanics model team assess the hydraulic fracturing disposal data at the DOE Oak Ridge facility. The Panel member noted there is literature that indicates land surface strain can occur from injection into shale at a shallow depth within the range of ORD's modeling. The Panel member recommended that ORD plan to illustrate the modeling processes and results, since models can provide a three dimensional visualization that helps the public's understanding of these processes. The Panel member noted that the modeling can identify critical monitoring and data collection needs to help focus EPA data gathering efforts. The Panel member also noted that several points raised in the modeling discussion at this SAB meeting are not incorporated into the model, and recommended that ORD clarify what those areas are in its reporting on its modeling work.

Another Panel member commented that ORD should recognize that hydraulic fracturing occurs during a very short period of time. The Panel member noted that hydraulic injection occurs only for about a one week period, and the highest pressure occurs during the final pumping that occurs after days of pumping. The Panel member noted that a key issue is the direction for hydraulic fractures that are formed during the fracturing process, and commented that hydraulic fractures occur along the annulus of the well and that it would be shocking if fractures occurred in the direction of groundwater. Dr. Moridis responded that Scenario 1 of the modeling was assessing fractures that may occur within the well bore. The Panel member noted that ORD's modeling reports should provide figures that indicate fractures along the well bore, and figures indicating fractures to the geologic layers.

Another Panel member recommended that the modeling scenario analysis should assess the risk probability, and analyze the possibility and the probability of whether well failures could cause releases during hydraulic fracturing (i.e., whether the risk of occurrence is one in a million, one in ten thousand, etc.). Dr. Moridis agreed this is an important issue that was raised to ORD's attention by Dr. George Pinder.

A Panel member commented that an integrated model is a depository of integrated knowledge of a system, developed as a community enterprise, and many people make the pieces for such models. The Panel member recommended that if EPA presents the model in its reports under an organized intellectual framework, with humility and good graphics, the public will understand ORD's modeling effort.

Responses to Charge Question 8: Effectiveness of Well Construction and Operation

Practices: *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.*

A Panel member commented that ORD's focus on 2009-2010 data from well files was short sighted, and noted that well construction and drilling technologies were changing at a fast rate. The Panel member recommended that ORD include discussion on such changes in its research reports. The Panel member noted that rapid changes in geophysics characterization technologies were occurring, in areas such as down hole monitoring, manufacturing techniques, and in smart well construction. The Panel member noted that data indicate that fractures are forming in unanticipated directions. The Panel member recommended that ORD document and integrate these data and case studies into its research.

Another Panel member recommended that ORD verify the validity of well data that it is considering in its research. The Panel member noted that while some record of well construction and diagrams may be in well files, the procedures for constructing the well may be in company files, and ORD should gather that information. The Panel member recommended that ORD gather petrophysical data such as imaging logs and data on rock mechanics in order to identify faults and hydraulic fractures, and collect data for the development of geological cross sections where multiple wells have been installed. The Panel member commented that such data (e.g., the petrophysical logs) are very complex, and recommended that ORD assign experts for the collection, database creation, and use of this information.

The Panel member recommended that ORD's data gathering effort should differentiate data collected from coalbed zones that produce gas, and differentiate which well casing sections have been cemented. The Panel member also recommended that ORD assess whether well casing should go to the top of the well. The Panel member noted that ORD could review acoustic logs that may have been collected by well owner/operators, and commented that this information may not be available within ORD's statistical selection of well log data. The Panel member suggested that ORD could review noise in these logs in combination with cement logs to identify problems associated with failed pressure tests. The Panel member also suggested that the subjective information provided through mud logs within well files provide useful data on gas in shallow zones. The Panel member recommended that ORD gather information on drilling procedures directly from companies since such data may not exist in well files.

One Panel member recommended that ORD compare cement log indices before and after hydraulic fracturing in order to rule out apparent incorrect signals, and always conduct multispectral analysis to identify changes over time and frequency of bonding. The Panel member recommended that ORD assess how pressure differences affect changes in flows, and commented that microseismic redistribution of stress affects transfer in rocks.

A Panel member commented that there is a tendency for overestimating stiffness and failures when assessing geomechanical properties through log data, and recommended that ORD gather and calibrate load data through laboratory testing. The Panel member also noted that industry was currently using fiber optics, temperature, pressure and acoustic sensors to conduct 24 hour monitoring along all points on wells. The Panel member stated that these sensors provide information on how stress or local deformation changes occur around wells, whether such changes are due to cement, and help assess microseismicity issues. The Panel member noted that over the last two to three years, there have been significant advances in identifying microseismic fractures through these techniques, and whether such fractures are new or forming through

nearby faults. The Panel member stated that various studies will soon be published on this topic in journals of the Society of Professional Engineers and the Society of Petroleum Geophysicists, and in other literature.

The Panel member noted that the introduction of fluids into formations may create incompatibilities with native fluids already in the formation, create chemical residues in formations, alter zones of saturation, and change the rate of perforation, effective stress, and fault failure. The Panel member also suggested that ORD assess realistic scenarios in its case study and modeling analyses.

A Panel member commented that there are uncertainties in interpreting geophysical data through deterministic methods, and that EPA should evaluate tools for assessing uncertainty associated with using such complex data.

A Panel member asked whether EPA was using well file data to characterize well construction effectiveness of well construction, and whether EPA was assessing the effectiveness of state regulations regarding well construction. Ms. Briskin responded that ORD will report the findings of its well-file analysis on how hydraulic fracturing occurred between 2009-2010. The Panel member commented that ORD was not making judgments on effectiveness, but was actually only researching frequency of occurrence. Mr. Wisner responded that EPA was analyzing frequency distributions on how wells were constructed, and that EPA would consider whether the analysis has implications on the effectiveness of well design and completion. Ms. Briskin clarified that its data analysis was occurring on 350 of 25,000 wells that have available data. A Panel member recommended that EPA identify the uncertainty associated with its selection of wells using stratified random sampling methods.

Clarifying Comments from Members of the Public

Dr. Dzombak noted that two members of the Public had requested to make clarifying statements for consideration by individual members of the Panel.

Ms. Elizabeth Tatham presented her clarifying comments as a stakeholder from Pennsylvania. Ms. Tatham commented that she appreciated the opportunity to learn about EPA's activities at the meeting, and had two recommendations for EPA. She noted that recent public comments have indicated an enormous public interest in hydraulic fracturing well spills. She referred to a spill that occurred on April 19, 2011 in Bradford, Pennsylvania, and noted that the release was not stopped until April 25, 2011. She also noted that a release in the form of a geyser occurred for 16 hours in Clearfield County, Pennsylvania in June 2010, and a crew was flown in from Texas to stop the release. She recommended that EPA include the Bradford site in its research. She also requested that the Panel and the public have access to ORD's research publications before those publications are finalized. Upon hearing no questions from the Panel, Dr. Dzombak then recognized the next public speaker.

Mr. Jeff Zimmerman, an environmental lawyer representing Damascus Citizens for Sustainability, presented his clarifying comments. Mr. Zimmerman commented that it would be a shame if ORD did not assess the Dimock, Pennsylvania and Pavillion, Wyoming sites as case studies in its hydraulic fracturing research, and noted there would be significant public reaction if those case studies were not included. He stated he was told that these two sites were not in EPA's Progress Report because the Superfund Program was addressing these sites. He noted that since many mistakes have occurred throughout the Superfund program, the two sites should

be included in EPA's research. Upon hearing no questions from the Panel, Dr. Dzombak then moved forward to the wrap up discussion.

[Note: Two emailed requests to make clarifying remarks sent during the public meeting were not received by the SAB Designated Federal Officer until after the meeting. Both emails were posted to the meeting webpage.^{15, 16}]

Wrap Up and Remaining Issues, Action Items and Next Steps

Mr. Zarba noted that a public teleconference of the Panel would not be held on May 16, 2013, since there were no additional public comments for consideration by Panel members that could not be accommodated at the May 7-8, 2013 face-to-face meeting.

Dr. Dzombak noted that since this is a consultation, the primary output from the meeting will be the Panel member's individual written comments in response to the charge questions. He requested that each Panel member send their individual expert written comments to the DFO, Edward Hanlon. He also noted that he will prepare a short letter to the EPA Acting Administrator, noting that we held a consultation on May 7-8, 2013. He stated that the letter will note that the Panel was convened under the auspices of the SAB to provide individual, rather than consensus, advice to the Agency at this interim stage of EPA's work related to research on the potential impacts of hydraulic fracturing on drinking water resources.

Dr. Dzombak noted that he and Edward Hanlon will be preparing minutes from the meeting, which would be posted onto the SAB meeting website. He noted that the SAB recognizes the need to keep the Panel as informed as possible with new and emerging information related to hydraulic fracturing, and that after the meeting, there will be opportunity for the public to provide such information to the Panel. He stated that the SAB Staff Office will provide notice in the Federal Register and on the SAB website on opportunities for doing that. He commented that the Panel will conduct a formal peer review of EPA's 2014 Report of Results, and noted that ORD may request SAB to review particular pieces of its research, or hold interim meetings with the SAB Panel. He also noted that the SAB may make requests for briefings from the Agency, and asked the Panel members to let him and DFO Edward Hanlon know if they had ideas for suggested briefing topics.

Mr. Zarba noted that if the Panel members would like to have a meeting to gather more information, please let Dr. Dzombak and Edward Hanlon know, and the SAB Staff Office would try to combine purposes for a meeting or teleconference if that would be appropriate. Mr. Zarba noted that the SAB Staff Office will also solicit information from outside organizations and the public through a Federal Register Notice.

Dr. Dzombak noted that the webcast of the May 7-8, 2013 Panel meeting was broadcast and not being recorded by the SAB Staff Office. Mr. Hanlon noted that copies of information handed out during the May 7-8, 2013 Panel meeting would be posted on the SAB meeting website.

Dr. Dzombak requested any additional comments from the Panel members. A Panel member noted that when ORD updates its diagrams that will be used in its research reports, ORD should engage communities for their input on how to best develop the diagrams. Another Panel member noted that EPA should provide more information to the Panel on the status of its prospective case studies.

A Panel member asked if the Panel members could have access to ORD datasets that are being developed. Dr. Dzombak responded that EPA has expressed concern about releasing information that has not gone through ORD's data quality objectives review, and also may have confidential business information issues. Another Panel member asked whether the minutes would be circulated to the Panel members for review. Dr. Dzombak responded that the draft minutes would be developed by himself and DFO Edward Hanlon, and that Mr. Hanlon would check with Panel members if any questions arose in interpreting his notes on statements made by Panel members during the meeting.

A Panel member asked whether the Panel could provide comments on EPA's uncertainty approach before such approaches were finalized. Another Panel member suggested that the Panel could provide input on ORD's uncertainty approaches in its watershed modeling approaches and uses for well log data. Dr. Dzombak responded that he would encourage ORD to provide information on its uncertainty approaches to the Panel.

Dr. Dzombak asked if the Panel members had any additional questions or comments. Hearing none, Dr. Dzombak noted the Panel was currently empanelled and would stay empanelled through 2015. He thanked the Panel members, EPA staff, SAB Staff Office, and contractor personnel who participated at the meeting. With the meeting business concluded, the Designated Federal Officer adjourned the meeting at 3:00 pm ET.

Respectfully Submitted:

/signed/

Mr. Edward Hanlon
Designated Federal Officer

Certified as Accurate:

/signed/

Dr. David A. Dzombak, Chair
SAB Hydraulic Fracturing Research
Advisory Panel

NOTE AND DISCLAIMER: The minutes of this public meeting reflect diverse ideas and suggestions offered by Panel members during the course of deliberations within the meeting. Such ideas, suggestions and deliberations do not necessarily reflect consensus advice from the Panel members. The reader is cautioned to not rely on the minutes to represent final, approved, consensus advice and recommendations offered to the Agency. Such advice and recommendations may be found in the final advisories, commentaries, letters or reports prepared and transmitted to the EPA Administrator following the public meetings or teleconferences.

Materials Cited

The following meeting materials are available on the SAB website (www.epa.gov/sab) or through the following SAB Hydraulic Fracturing Research Advisory Panel May 7-8, 2013 meeting webpage:

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

¹ April 5, 2013 Federal Register Notice announcing the public meeting (78 FR 20637 – 20638)

² Agenda for May 7-8, 2013 public meeting

³ EPA Presentation - Introduction-May 7, 2013

⁴ Public comments submitted by Tatham, Elizabeth 5-7-13

⁵ Public comments submitted by Carty, Susan 5-7-13

⁶ Public comments submitted by Jones, Jessica on behalf of the League of Women Voters, 5-6-13

⁷ Public comments submitted by Thorp, Lynn on behalf of Clean Water Action 5-6-13

⁸ Public comments submitted by Nevin, Don. 5-7-13

⁹ EPA Presentation - Water Acquisition-May 7, 2013

¹⁰ EPA Presentation - Chemical Mixing-May 7, 2013

¹¹ EPA Presentation - Flowback and Produced Water-May 7, 2013

¹² EPA Presentation - Wastewater Treatment and Disposal-May 8, 2013

¹³ EPA Presentation - -Wastewater Treatment and Wastewater Disposal. List of Analytes Handout

¹⁴ EPA Presentation - Well Injection-May 8, 2013

¹⁵ Public comments submitted by Egged, James. 5-7-13

¹⁶ Public comments submitted by Cowan, Dave. 5-8-13

ATTACHMENT A – ROSTER

U.S. Environmental Protection Agency Science Advisory Board Hydraulic Fracturing Research Advisory Panel

CHAIR

Dr. David A. Dzombak, Walter J. Blenko Sr. University Professor, Department of Civil and Environmental Engineering, College of Engineering, Carnegie Mellon University, Pittsburgh, PA

PANEL MEMBERS

Dr. Stephen W. Almond, Technical Director, Oilfield Chemicals, Specialty Chemicals Division, MeadWestvaco Corporation, Charleston, SC

Dr. E. Scott Bair, Professor, School of Earth Sciences, Ohio State University, Columbus, OH

Dr. Peter Bloomfield, Professor, Statistics Department, North Carolina State University, Raleigh, NC

Dr. Steven R. Bohlen, Deputy Program Director for Energy and Environmental Security, Office of Strategic Outcomes, Lawrence Livermore National Laboratory, U.S. Department of Energy, Livermore, CA

Dr. Elizabeth W. Boyer, Associate Professor, Department of Ecosystem Science & Management, Pennsylvania State University, University Park, PA

Dr. Susan L. Brantley, Distinguished Professor of Geosciences and Director, Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA

Dr. James V. Bruckner, Professor of Pharmacology and Toxicology, Department of Pharmaceutical and Biomedical Sciences, College of Pharmacy, University of Georgia, Athens, GA

Dr. Thomas L. Davis, Professor, Department of Geophysics, Colorado School of Mines, Golden, CO

Dr. Joseph J. DeGeorge, Global Head of Safety Assessment and Laboratory Animal Resources, Merck Research Laboratories, Lansdale, PA

Dr. Joel Ducoste, Professor, Civil, Construction, and Environmental Engineering Department, North Carolina State University, Raleigh, NC

Dr. Shari Dunn-Norman, Professor, Geological Sciences and Engineering, Missouri University of Science and Technology, Rolla, MO

Dr. Katherine Bennett Ensor, Professor and Chair, Department of Statistics, Rice University, Houston, TX

Dr. Elaine M. Faustman, Professor, Department of Environmental Health, and Director, Institute for Risk Analysis and Risk Communication, School of Public Health, University of Washington, Seattle, WA

Mr. John V. Fontana, President, Vista GeoScience LLC, Golden, CO

Dr. Daniel J. Goode, Research Hydrologist, United States Geological Survey, Exton, PA

Dr. Bruce D. Honeyman, Department of Civil and Environmental Engineering, Colorado School of Mines, Boulder, CO

Mr. Walter R. Hufford, Director of Government and Regulatory Affairs, Talisman Energy USA Inc., Warrendale, PA

Dr. Richard F. Jack, Manager of Market Development, Thermo Fisher Scientific Corporation, San Jose, CA

Dr. Dawn S. Kaback, Principal Geochemist, AMEC Environment and Infrastructure, Inc., Denver, CO

Dr. Abby A. Li, Senior Managing Scientist, Exponent Health Sciences, Exponent, Inc., San Francisco, CA

Mr. Dean Malouta, Independent Consultant, Houston, TX

Dr. Cass T. Miller, Daniel A. Okun Distinguished Professor of Environmental Engineering, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC

Dr. Laura J. Pyrak-Nolte, Professor, Department of Physics, College of Science, Purdue University, West Lafayette, IN

Dr. Stephen Randtke, Professor, Department of Civil, Environmental, and Architectural Engineering, University of Kansas, Lawrence, KS

Dr. Joseph N. Ryan, Professor of Environmental Engineering and Bennett-Lindstedt Faculty Fellow, Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder, Boulder CO

Dr. James E. Saiers, Professor of Hydrology and Associate Dean of Academic Affairs, School of Forestry and Environmental Studies, Yale University, New Haven, CT

Dr. Eric P. Smith, Professor and Head, Department of Statistics, Virginia Polytechnic Institute and State University, Blacksburg, VA

Dr. Azra N. Tutuncu, Professor and Harry D. Campbell Chair, Petroleum Engineering Department, and Director, Unconventional Natural Gas and Oil Institute, Colorado School of Mines, Golden, CO

Dr. Paul K. Westerhoff, Associate Dean for Research in the Ira A. Fulton Schools of Engineering, and Professor, School of Sustainable Engineering and The Built Environment, Arizona State University, Tempe, AZ

Dr. Thomas M. Young, Professor of Civil and Environmental Engineering, University of California – Davis, Davis, CA

SCIENCE ADVISORY BOARD STAFF

Mr. Edward Hanlon, Designated Federal Officer, U.S. Environmental Protection Agency, Science Advisory Board Staff, Washington, DC

ATTACHMENT B – Other Attendees

List of Members of the Public (from Sign-in Sheets) Who Attended the May 7-8, 2013 Public Meeting, Who Requested Information on Accessing the Teleconference line or Live Webcast, or Who Noted Via Email That They Participated On the Live Webcast:

May 7-8, 2013

Name	Affiliation
Allen, David*	University of Texas
Babcock, Sarah**	No Affiliation Given
Bair, Julie	No Affiliation Given
Baker, Tim**	Oklahoma Corporation Commission
Beck, Nancy*	American Chemistry Council
Berthiaume, Alicia**	Environment Canada
Bethel, Heidi L.**	EPA
Brennan, Thomas	EPA
Briskin, Jeanne	EPA
Bufare, Talic	Politico
Burden, Susan	EPA
Bush, Pamela F.*	Maryland Department of Natural Resources
Calamai, Ann	EPA
Carpenter, Adam	American Water Works Association
Carpenter, Thomas	EPA
Carty, Susan	No Affiliation Given
Ceballos, Kelly**	League of Women Voters of the U.S.
Cowen, Dave**	Greenbrier River Watershed Association
Cox, John	Jo-Carroll Energy
Deal, Tori*	State of Florida Department of Environmental Protection
Dean, Jill**	EPA
DiCosmo, Bridget	Inside EPA
Dobson, Natenna**	U.S. Department of Energy
Drunich, S.Van	EPA
Dunlap, David	KCPS

Name	Affiliation
Easley, Kevin*	U.S. Department of Energy
Egged, James* **	Sierra Club
Ford, Libby*	Nixon Peabody, LLP
Francis, Dick**	Shell - Upstream Americas
Frithsen, Jeffrey	EPA
Gabelich, Christopher**	Metropolitan Water District of Southern California
Gee, Sarah*	Ecolab
Goodwin, Richard W.**	No Affiliation Given
Harris, Jamie**	EPA
Hauchman, Fred	EPA
Hewitt, Caitlir	OCY
Hill, Bruce	CATF
Hill, Chris	Chesapeake Energy
Houk, Virginia**	EPA
Hover, Leigh	EPA
Impellitteri, Chris	EPA
Jensen, Mark E.**	State of Utah Department of Environmental Quality
Jollie, Jeff**	EPA
Jones, Jessica	League of Women Voters of the U.S.
Kane, Kimberlee**	New York City Department of Environmental Protection
Kraemer, Stephen	EPA
Lan, Naomi	Government of Ontario, Canada
Larrea, John*	California League of Food Processors
LeDue, Stephen	EPA
Marshall, Mike*	No Affiliation Given
Martinez, Barbara	EPA
Mason, Diedre	Association of State Drinking Water Administrators
Mattugley, Joe	Jo-Carroll Energy
Mauriello, Tracie	Pittsburgh Post Gazette
McDonnell, Tim* **	Climate Desk

Name	Affiliation
McFadden, Angela* **	No Affiliation Given
Meadows, Stephanie	American Petroleum Institute
Meza-Cuadra, Claudia	EPA
Muegge, John**	State of California Hazardous Waste Management Program
Nara, Peter L.**	Biological Mimetics, Inc.
Nevin, Don	Lamnpipe Inc.
Nugent, Angela	EPA
O'Connor, Kathleen**	New York State Energy Research and Development Authority
Orme-Zavaleta, Jennifer	EPA
Paulson, Glenn	EPA
Pearen, Holly**	Environmental Defense Fund
Pope, Peter G.**	Railroad Commission of Texas
Ridley, Caroline	EPA
Roberts, Cindy	EPA
Savoury, Robert*	Government of Northwest Territories, Canada
Schendle, Jason**	Alpine Group, Inc.
Schumacher, Brian**	EPA
Sharkey, Susan**	EPA
Sherr, R. Kirk**	Clearview Strategy Group, LLC
Sierra, Fernando*	Shell - Upstream Americas
Sonich-Mullin, Cynthia**	EPA
Soraghan, Mike	Environment and Energy Publishing
Sotelino, Daniel	Natural Resources Defense Council
Sundown, Mardell**	Tonawanda Seneca Nation
Tatham, Elizabeth	No Affiliation Given
Thorp, Lynn	Clean Water Action
Trovato, Ramona	EPA
van Rossum, Maya*	Delaware Riverkeeper Network
Wayner, Katie	No Affiliation Given
Weber, Andrea*	Center for Biological Diversity

Name	Affiliation
Weber, Daniel**	Alaska Department of Environmental Conservation
Wentworth, Nancy**	No Affiliation Given
White, Kim Tuthill**	Baker Botts L.L.P.
White, Russell**	American Petroleum Institute
Williams, James A. II*	Environmental Technology Council
Wind, Martin J.**	Muscogee Creek Nation
Woods, Clint**	U.S. House of Representatives Committee on Science, Space, and Technology
Zamzow, Kendra	EPA
Zambrana, Jose	EPA
Zimmerman, Jeff	Damascus Citizens

* Member of public who participated or requested information for calling into the meeting.

**Member of public who indicated that they participated via Webcast, or requested information for participating via Webcast.