Suggested Topics for Discussion
From Dr. David Dzombak, Chair of EPA Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel

In Preparation for the Panel's February 1, 2016 Teleconference

U.S. EPA Science Advisory Board
1200 Pennsylvania Ave., N.W.
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<u>As of January 28, 2016</u>

Suggested Topics for Discussion from Dr. David Dzombak, Chair of EPA Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel, In Preparation for the Panel's February 1, 2016 Teleconference

Purpose: This is a preliminary list of topics for discussion from Dr. David Dzombak, Chair of the SAB Hydraulic Fracturing Research Advisory Panel, in preparation for the Panel's February 1-2, 2016 SAB Panel teleconference call. These discussion topics have been compiled, with grouping and some editing for clarification, by David Dzombak from individual Panel member comments associated with the Panel's review of the Panel's January 7, 2016 draft report entitled *SAB Review of the EPA's draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources*. The draft SAB Panel report has been posted onto the SAB's February 1, 2016 teleconference website at: http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/5fca4c1a644cdc8085257f17006e7272!OpenDocument&Date=2016-02-01

Page and line references noted below refer to the page and line number of the Panel's January 7, 2016 draft report that is available on the above-noted website.

General Comments:

1) General advice to perhaps be bolstered with specific advice: In the draft SAB report, there are several comments that appear to provide general advice that could perhaps be bolstered with specific advice or suggestions on how the EPA could or should address the issue (e.g., by reviewing specific data sources or gathering other specific information). Several specific areas of the draft responses to charge questions are noted in Appendix 1 of this document.

2) Proposal to use 2/1/16 Panel teleconference to identify SAB Panel advice that must be addressed in order to finalize the draft Assessment Report as expeditiously as possible:

   A Panel member noted the following: "Although I agree with the vast majority of the specific points raised in the SAB's draft Report to the Administrator, I fear that the totality of the comments might lead to undesirable delays in completing this report and/or the expenditure of resources that could be used in better ways to address the risks associated with hydraulic fracturing. Many of the SAB recommendations indicate the need for substantial new data collection and analysis (e.g., examination of 20,000 well logs, collection and reanalysis of FracFocus data in newer versions of the database, examination of a broader set of spill reports). I am concerned that, if EPA chooses to conduct these additional activities it will consume a significant amount of time and agency resources without substantially decreasing the associated uncertainties because the nature of the underlying data and its limitations has not fundamentally changed (i.e., it will be "more of the same"). A report such as this one can never be said to be truly complete (since knowledge and industry practices continually evolve) and can never be completely up-to-date (because the peer review process inevitably introduces time lags). I would suggest that, in our upcoming teleconference, we review our comments to differentiate between those that must be addressed to ensure that the report does not create a false sense of assurance that hydraulic fracturing has been ***proven*** to have

minimal impacts on water resources and those that constitute recommendations for additional data collection or future research. In my opinion, the first category would contain comments related to correcting inaccurate or imprecise statements like the much discussed point on page ES-6 regarding systemic impacts, while the second would include most of the additional data gathering or literature review activities."

Taking the broadest possible view of the EPA report and the SAB process to date including review of the study plan, the progress report and the draft final report, I would provide the following summary:

A. EPA conducted a massive review of the available information and literature related to drinking water impacts of hydraulic fracturing. Although there are certainly items they could have included and did not, this was a fairly comprehensive effort. The research plan promised retrospective and prospective case studies but these were not conducted.
B. The EPA review found few well-documented cases of drinking water impacts associated with hydraulic fracturing operations and concluded there were no "widespread systemic impacts on drinking water resources".
C. The SAB, noting the general unavailability of systematic and appropriately targeted monitoring data related to water quality and quantity impacts, was uneasy that the report would be taken as a final determination that hydraulic fracturing posed no risks to water quality. The SAB seeks many changes to the report, including substantial additional analysis and data collection, to try to improve its comprehensiveness. However, I believe the existing report shows that piecing together the available evidence cannot lead to an integrated picture of the risks associated with HF operations.

   My recommendation is that the existing report should be finalized as expeditiously as possible, and with minimal additional resources, by correcting key statements that are misleading, unsupported or imprecise and by adding a chapter on future research needs. The agency should then design a companion study that focuses on collecting the data required to best address the uncertainties and knowledge gaps identified in this report. I believe that will require, at a minimum, agency-sponsored field investigations that involve collection of original data such as the retrospective and prospective case studies described in the original study plan."

Cover Letter to the Administrator

1) SAB's general finding that the EPA's overall approach was appropriate and comprehensive

A Panel member suggested that the Panel discuss the statement made on p. 1, lines 36-42, that notes: "In general, the SAB finds the EPA's overall approach to assess the potential impacts of hydraulic fracturing for oil and gas on drinking water resources, focusing on the individual stages in the HFWC, to be appropriate and comprehensive. The SAB also finds that the agency provided a generally comprehensive overview of the available literature that describes the factors affecting the relationship of hydraulic fracturing and drinking water, and adequately described the findings of such published data in the draft Assessment Report."

2) Key finding on widespread systemic impacts

P.2, lines 1-7, of the draft SAB report notes: "Of particular concern in this regard is the high-level conclusion statement on page ES-6 that "We did not find evidence that hydraulic fracturing mechanisms have led to widespread, systemic impacts on drinking water resources in the United States." The SAB finds that this statement does not clearly describe the system(s) of interest (e.g., groundwater, surface water) nor the definitions of "systemic," "widespread," or "impacts." The SAB is also concerned that this statement does not reflect the uncertainties and data limitations described in the body of the Report associated with such impacts. The statement is ambiguous and requires clarification and additional explanation."

- A Panel member noted that: "In a number of places we say the Executive Summary is ambiguous and the conclusions ARE inconsistent. Since we don't have clarity on what the major findings are, we cannot say they are inconsistent with the data, but that they *appear* inconsistent. Once clearly defined, they may be very aligned with the data. If "systemic, widespread and impact" were to be defined as occurring in high frequency (majority of wells" across all drilling locations, with substantial and long term degradation to water quality that harmed human health, such a conclusion could be supported by the data as presented. Such an observation would have been apparent even with the data gaps and it would not contradict the observations of severe local impact at low frequency. I think we need to await the definitions before declaring if the conclusions are or are not in conflict with the data in the report."

  Another Panel member noted that: "The report is correct in stating there are no systemic issues with groundwater associated with HF operations. I concur with the EPA finding as written. This finding does not suggest that a local impact or issue should be marginalized for the communities in which an incident occurs."

  Another Panel member suggested adding the following sentences after this language on p.2, lines 1-7, of the draft SAB report: "To be clear, the SAB recognizes the significant environmental impacts to groundwater that have been cited by members of the public and respectfully requests that the EPA report more fully address such incidents and circumstances. The SAB is, however, wary of condemning all hydraulic fracturing activities nationwide with a broad brush if such accusations are not supported by data, or

if reasonable expectation exists that the circumstances, which resulted in those problems, cannot be universally or even generally extrapolated."

3) *Recommendations to add an additional major finding*

- P.3, lines 7-11 recommends that the EPA include an additional major finding: "The EPA should also include an additional major finding that: (a) large severe hydraulic fracturing flowback and produced water-related contaminant release incidents such as blowouts, and smaller common incidents (usually containment leaks), may cause effects on drinking water resources on a volume basis; and (b) blowouts are more severe in terms of impact due to the high-volume, short-duration characteristics of the release."

  A few Panel members noted they did not understand this recommendation to include the above noted major finding. Another Panel member asked "What does "on a volume basis" mean in this sentence (and why is it needed?)"

4) Studies at Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas

p. 2, lines 19-27: The draft cover letter, Executive Summary and comments to various charge questions note that: "The SAB recommends that the agency should include and explain the status, data on potential releases, and findings if available for the EPA and state investigations conducted in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas where hydraulic fracturing activities are perceived by many members of the public to have caused significant local impacts to drinking water resources. Examination of these high-visibility cases is important so that the public can understand the status of investigations in these areas, conclusions associated with the investigations, lessons learned for hydraulic fracturing practice if any, plans for remediation if any, and the degree to which information from these case studies can be extrapolated to other locations."

- A Panel member noted that: "The report should not be diminished in its entirety due to a focus on the three sites (Pavillion, Dimock, and Parker County). I refer the panel to the recent submittals on at least two of those sites by the state regulatory agencies who are working on these locations."

- A Panel member noted that: "I feel that the SAB report is too soft in the EPA ignoring the 3 cases that have captured the US's news media and presses attention (i.e., Dimock, Pavillion and Parker County) though out the Draft SAB document. These studies and lessons learned from these studies must be included." The Panel member further noted that the Panel should discuss: "The need to tie-back issues of poor well construction to actual case histories in Dimock, Pavillion and Parker Count with at a minimum of relative probability causal relationship."

- Another Panel member noted that: "The draft SAB comment involves currently-existing data, 'if available'. Should we be more explicit and request that a study commence in one of those areas if the data are currently not sufficient to understand the potential problem in the area? Should an oversight group be charged with reviewing the data from one (or all) of these areas given the politically-charged nature of the complaints?"

5) *Recommendation to add another key point to the cover letter:*

A Panel member noted that: "The only point I feel missing is a mapping exercise that identifies water treatment plants that have HF activities occurring in its watershed, and the 1-mile designation currently used is arbitrary and irrelevant when it comes to surface water supplies. It may be, marginally, acceptable for ground/well water supplies."

6) *Clarify reasoning for distinguishing potential impacts unique to HF from impacts from conventional non-HF development:*

p.3, lines 36-43, of the draft SAB cover letter, and p. 4, lines 23-30 of the Executive Summary, notes: "The EPA should carefully distinguish between hydraulic fracturing chemicals injected into a hydraulic fracturing well vs. compounds that come back out of the hydraulic fracturing well in produced fluids, and between those chemical constituents and potential impacts unique to hydraulic fracturing oil and gas extraction from those that also exist as a component of conventional oil and gas development. The agency should also clarify whether compounds identified as being of most concern in produced water are products of the hydraulic fracturing activity, flowback, or late-stage produced water, or are chemicals of concern derived from oil and gas production activities that are unrelated to hydraulic fracturing activity." This issue is also discussed on p. 57, lines 29-31.

- A Panel member noted that: "The letter needs to be clearer about the reason for distinguishing potential impacts that are unique to HF from those that exist in conventional non-HF development. It may be an important technical distinction, but it would immaterial to anyone whose drinking water was impacted by HF development of a well."

- Another Panel member noted that: "Such an assessment would require a substantial amount of additional work. For example, a modeling approach would need to account for the complex mixtures actually injected, which are often non-Newtonian fluids; be based upon physicochemical properties at the pressures and temperatures of the formation; be able to resolve the unstable flow patterns resulting from the injection of a less dense fluid into a denser brine, which is the typical situation; and account for the many biogeochemical reactions that are operative in the subsurface but not included in the modeling performed to date. If such an analysis is done, a natural place for this might be in Chapter 7 of the EPA's draft Assessment Report which discusses flowback water."

7) *Most likely exposure scenarios and hazards*

P. 3, lines 25-26 of the cover letter note: "The agency should identify the most likely exposure scenarios and hazards." P. 16, lines 42-43, of the Executive Summary notes: "The agency should identify the most likely exposure scenarios and hazards in order to obtain toxicity information relevant to particular situations."

A Panel member noted that: "This sentence from the main body of report should be better highlighted: Could this activity lead toward a prioritization of effort? This is the kind of

activity that I think is important to do: identify the most important and likely and common scenarios of contamination. This can help focus emphasis for research or monitoring."

8) Background and pre-existing baseline chemistry of surface and groundwater

p. 4, lines 1-4, and p. 13, lines 45-47, note that: "The EPA should also include additional discussion on background and pre-existing baseline chemistry of surface and groundwater in order to better understand the impacts of hydraulic fracturing-related spills and leaks."

- A Panel member noted that: "One of the most visible public issues is the appearance of contaminated or degraded water wells in areas where hydraulic fracturing occurs. We saw several jugs of dirty water brought to the public meetings by impacted citizens. The report generally skimmed over the topics relative to how science is used to distinguish between naturally occurring gases and contaminants, wells degraded from normal operation, and actual impacts from oil and gas well releases. The report should emphasize that the science required to distinguish between these conditions is complicated at best. There are many sophisticated geochemical tools that can be used to analyze gas composition, isotopes, anions and cations along with time series data in ground water to help distinguish the causes and effects of what may appear in a water well or aquifer, and these tools are best used with the collection of both baseline and post-drilling sampling. When baseline data are not available, interpretation of the data is more complicated and can be inconclusive as a result."

  The Panel member suggested adding the following language to this sentence in the cover letter to incorporate these concerns: "A major public concern is the appearance of contaminated or degraded drinking water wells in areas where hydraulic fracturing occurs. Since naturally occurring contaminants and degraded wells can occur from issues not related to hydraulic fracturing, the EPA should also include additional discussion on how background and pre-existing baseline chemistry of surface and groundwater data is used in order to better understand the impacts of hydraulic fracturing-related spills and leaks."

  Another Panel member stated that it is unclear what exactly the SAB is requesting of the EPA. Addressing baseline chemistry conditions in detail could be quite a substantial effort. For example, development of guidance for baseline chemistry evaluation would involve more than just a short discussion.

Executive Summary, and Chapter 10: Synthesis of Science on Potential Impacts of Hydraulic Fracturing on Drinking Water Resources (Charge Question 8)

1) Prospective Studies:

In the draft Report's Executive Summary, p. 3, lines 8-18 note that: "the EPA should continue research on expanded case studies and long-term prospective studies, and should place a high priority on conducting additional field studies in order to develop a much more comprehensive chemical exposure database. The draft Assessment Report should identify needs for future research, assessment and field studies, and discuss the agency's plans for conducting prospective studies and other research that the EPA had planned to conduct but did not conduct. The lack of prospective case studies as originally planned by the EPA and described in the research Study Plan (U.S. EPA, 2011) is a major limitation of the draft Assessment Report. Such studies would allow the EPA to monitor water acquisition and its effects to a level of detail not practiced by industry or required by state regulation. Such detailed new data would allow the EPA to reduce current uncertainties and research gaps about the relation between hydraulic fracturing water acquisition and drinking water."

- A Panel member noted that: "The prospective studies which were contemplated in the original work scope by the agency did not progress for a number of reasons. While the report does not describe this in detail, it should be noted that industry worked closely with the agency, and expended considerable resources on locations that were later deemed not appropriate. Regardless of the issues on why this aspect did not go forward, it is important the agency look at the literature and research completed since the initiation of the investigation and use that data in lieu of advancing a new prospective study. I believe a June 2015 report from Yale is an example of this research the agency should consider and incorporate into their document."

- Another Panel member noted that: "The lack of EPA's charge to perform "five to ten in-depth studies to be conducted at locations selected to represent the full range of regional variability of hydraulic fracturing across the nation" is clearly not included and must be."

- Regarding the sentence: *"Such studies would allow the EPA to monitor water acquisition and its effects to a level of detail not practiced by industry or required by state regulation*", a Panel member noted: "This statement should be modified / clarified to acknowledge the fact that some states require pre-drilling baseline sampling, and I suspect at least some industry folks support this, or even do their own baseline monitoring, to help demonstrate that they are not contaminating local water supplies. As stated, it's a matter of the level of detail. A good research study would collect a lot more data and might help guide future baseline sampling programs. It sounds simple, but given the variability of water quality, especially in small streams and shallow wells, and other possible sources of chemical spills, baseline sampling needs to be done very well to be useful in determining the occurrence or source of suspected contamination. Perhaps we could say: "… to a level of detail not achieved by current industry pre-drilling practices and state baseline monitoring requirements."

2) Data Availability

- A) In the draft Report's Executive Summary, p. 3, lines 20-22 note that: "The agency provided limited information on the magnitude of hydraulic fracturing spills and estimated the frequency of on-site spills based upon information from two states, and the SAB agrees that these estimates cannot be confidently extrapolated across the entire U.S. based on such limited information." In the draft Report's Executive Summary, p. 11, lines 39-43 note that: "The SAB also notes that the EPA can reduce uncertainties associated with hydraulic fracturing cement and casing integrity by examining and assessing more or all of the 20,000 well files referenced in the draft Assessment Report. The SAB also recommends that the EPA conduct full statistical analyses on such an expanded Well File Review, and include graphs or tables associated with such analyses into the draft Assessment Report."

  A Panel member noted that: "I am concerned that we seem to make contradictory recommendations about whether extrapolations should be made based on small data sets. When discussing spills, we challenge the extrapolation of data from records from two states to the totally of wells. Yet later in the response we suggest an evaluation of 20, 000 well records to extrapolate to all wells as evidence of frequency of well completion issues. I would suggest that we recommend both types of extrapolations be included, but that the caveats and limitations of both (and other extrapolations) be discussed, but that they are useful to draw."

  Regarding the draft recommendation to examine and access more or all of the 20,000 well files, another Panel member noted that: "What exactly does this mean? Again, this seems like a daunting task…is this a worthwhile activity?"

  Another Panel member noted that: "When considering the creation of additional data sets from, for example, the well log data of the 20,000 wells it would be worthwhile to obtain the data according to a well-designed statistical plan, such as a stratified random sample or multistage sampling plan. A statistically designed study would allow for proper inference to the population level, while uncovering information on key variables in a cost effective manner both in terms of time and money. "

- B) In the draft Report's Executive Summary, p. 3, lines 30-32 note that: "The agency should synthesize information that is collected by the states but not available in mainstream databases, such as well completion reports, permit applications and the associated water management plans.

  A Panel member noted that: "This sentence in the report seems daunting to me. This is a huge, huge task. Do we really want to ask EPA to do this? What aspect of this is most important? Can the idea be refined?"

- C) In the draft Report's Executive Summary, p. 4, lines 1-2 note that: "Since the FracFocus data that the agency assessed was current up to February 2013, the SAB also recommends that the draft Assessment Report include data from more recent versions of FracFocus."

  A Panel member noted that the Panel should discuss the importance of reviewing the more recent (post 2013) FracFocus, especially considering the changes in chemical practices and focus by the oil and gas industry to replace specific chemicals like nonylphenolethoxylates in the surfactant type and diesel in the solvent type.

- D) In the draft Report's Executive Summary, p. 4, lines 18-19 note that: "The SAB recommends that the EPA conduct its own analysis of flowback water for organic compounds, since flowback water composition data are limited and the majority of available data are for inorganics.

  A Panel member noted that: "Here is another sentence describing a huge task we are asking EPA to do. This is difficult, costly, and time consuming. Is this what EPA should be asked to do?"

- E) P. 9, lines 27-29, and p. 38, lines 1-4, recommend that the EPA do the following activities: "Gather data and reference information regarding the efficiency of different mixing steps and delivery from mixing and delivery operations that are common and employed in other industries."

  A Panel member noted that: "Is the experience of "other industries" relevant to HF activities in remote, rural areas? Data and "reference information" from mixing beverage ingredients in an urban warehouse would be largely irrelevant. Mixing farm chemicals might be more relevant for chemicals that are mixed in the field near the point of application, but are reliable "data and reference information" available for this industry? If we are going to make such a recommendation we should recommend something both relevant and practical. I'm not sure this would be a worthwhile exercise, given the very significant differences likely to exist among industries, even ones using "similar" mixing steps and equipment. Without "calibration," etc., the uncertainty would be high and the results speculative and probably no better and perhaps worse than those derived from existing data for HF activities."

- F) P. 9, lines 39-42 recommends that the EPA do the following activities: "Utilize existing substantial databases from analogous operations to critically 'rank' the likelihood of hydraulic fracturing mixing and delivery operations for failure leading to spills (since the SAB agrees that the types of industrial processes used during hydraulic fracturing 'mixing' and delivery operations are not unique to hydraulic fracturing)."

  A Panel member noted that: "Although there may be nothing conceptually different compared to other industrial processes, there is a huge "psychological" difference between mixing chemicals in an urban warehouse in a city with a well written and enforced ordinances (e.g., a sewer use ordinance) and mixing chemicals near a well out

"in the middle of nowhere." And in either case is there any reason to believe the data are accurate enough to be relied upon for research, policy-making, or other purposes?"

3) Statement on extent of fracture zone:

In the draft Report's Executive Summary, p. 11, lines 45-46, and p. 12, lines 1-2, note that: "The conclusory discussion in Chapter 6 notes that fractures created during hydraulic fracturing can extend out of the target production zone and upwardly migrate. The EPA should delete these conclusions from the draft Assessment Report unless the EPA supports these statements with data or modeling."

A Panel member noted that: "One definition of "conclusory" is: "consisting of or relating to a conclusion or assertion for which no supporting evidence is offered". Are we saying that *all* the discussion in Chapter 6 is unsupported? If so, that needs to be stated more strongly than characterizing it as "conclusory", the connotations of which might not be known by many readers. If not, we should be more specific about which part of the discussion is unsupported."

4) Discussion on fate of un-recovered fracture fluids:

In the draft Report's Executive Summary, p. 13, lines 6-8 note that: "The EPA should discuss what happens to un-recovered fracture fluids that are injected into hydraulic fracturing wells, and assess where these fluids go if they do not come back to the surface.

- A Panel member noted that: "Doing so is going to require a much more sophisticated modeling approach than that used to date, since the injected fluids are many component, frequently non-Newtonian mixtures injected in an unstable environment with a wide range of biogeochemical reactions operative that have not been considered.

5) Discussion on deep well injection siting proximity to water intakes/supply:

In the draft Report's Executive Summary, p. 14, lines 45-46 note that: "The EPA should further assess how deep well injection siting proximity to production wells, water intakes and water supply wells may influence potential impacts on drinking water quality.

- A Panel member noted that: "Are we asking for assessment of deep well injection? If so, this seems too broad to me."

Chapters 1, 2 and 3: Goals, Background and History of the Assessment (Charge Question 1)

1) Hydraulic fracturing stage vs. hydraulic fracturing water cycle

- P. 22, lines 36-44, and p. 23, lines 1-2, note that: "As stated on page 1-2 of the draft Assessment Report, the scope of the assessment is "defined by the HFWC" and it is desirably broad, in particular not limiting it solely to the actual hydraulic fracturing step [stage]. The EPA should include provide additional explanation of the rationale for its choice to use the HFWC to assess impacts of hydraulic fracturing on drinking water resources. The EPA should discuss in the draft Assessment Report whether all of the ways in which hydraulic fracturing and related activities might impact the quality or quantity of drinking water resources are associated with one of the five stages of the cycle. The EPA should include text to describe why the EPA assessed certain HF-related topics and issues within the draft Assessment Report, and why certain hydraulic fracturing topics, issues and activities were considered to be out of scope for this assessment. Also, the EPA should consistently revise text throughout the draft Assessment Report when referring to hydraulic fracturing to note the EPA is referring to the entire HFWC, consisting of the five stages defined in this assessment.

  A Panel member noted that: "Regarding the rather narrow definition of the 'hydraulic fracturing step[stage]' as opposed to the impact of the broader hydraulic fracturing operations (the hydraulic fracturing water cycle, i.e., HFWC) on water supplies: Some critics of the draft SAB report have accused the SAB of 'mission creep' by expanding the review to the HFWC. I believe it was certainly the intent of Congress to examine the HFWC but, if this definition issue is seen as a problem, i.e., a distraction from the report by some, then maybe it should be addressed directly in the letter of transmission or the Executive summary. Or maybe it's a non-issue."

  Note from David Dzombak: The EPA decided to focus on the five stages of the HFWC in their Research Scoping Document and the detailed Study Plan subsequently developed. This broad approach was supported by the SAB Panels that reviewed those documents. The intent of the discussion on pp. 22-23 of the current draft SAB report on this topic, cited above, was to recommend that the EPA repeat in the Introduction of the Assessment report the rationale that was provided in the Research Scoping Document and the Study Plan. We discussed this at our October 28-30 meeting. The additional explanation recommended in our pp.22-23 comment will provide more background for readers of the report. Perhaps the wording on pp. 22-23 can be modified to improve clarity.

2) FracFocus data

- P. 27, lines 33-32, and P. 31, lines 36-45, note that: "The draft Assessment Report relied heavily on two publicly available databases that provide only limited capability to assess the sources and quantities of water used in the hydraulic fracturing process: a) the FracFocus Chemical Disclosure Registry database, where major limitations include questions regarding data completeness (e.g., including information from all wells in an area), the absence of information considered proprietary for certain chemicals, and lack

of information on the identity, properties, frequency of use, magnitude of exposure, and toxicity potential for a substantial number of chemicals; and b) the Water Use in the United States database from the USGS, where major limitations are associated with limitations of the spatial and temporal scale of the data (e.g., information not available at sub-county scales, and information on water used in hydraulic fracturing reported as part of larger categories of mining water use)."

Several Panel members suggested deleting the following clause, as they find it is not relevant to the discussion on water use: "the absence of information considered proprietary for certain chemicals, and lack of information on the identity, properties, frequency of use, magnitude of exposure, and toxicity potential for a substantial number of chemicals"

The Panel members suggested deleting this clause because it is not relevant to the discussion on water use, and because this clause appears to contradict the Charge Question 7 response which disagrees with EPA's characterization of the toxicology data by not taking full advantage of relevant data.

3) *Inconsistent use of terms describing temporary or limited events:*

- P. 30, lines 9-19 notes that: "*c.3. Are there other major findings that have not been brought forward?* There are several other major findings that the EPA should consider bringing forward. First, it should be more clearly noted that the stresses on water resources from water acquisition for hydraulic fracturing are expected to be local and temporary, and not to understate the potential for localized problems. Several of the public commenters, for example, expressed concern with surface waters taken from small rivers or streams. In such cases the timing of water withdrawals with relation to flow conditions is important, since withdrawals during low flow periods may result in dewatering and severe impacts on small streams. More attention needs to be given to describing the potential impacts on water resources at "hot spots" in space (e.g., headwater streams) and in time (e.g., seasonally, and/or under low flow conditions)."

  Several Panel members noted that: "There needs to be clarity between event times versus health impact times, and stated that a temporary event could result in a chronic or long impact. The Panel members also noted that a relatively small spill event or one limited in geographic scale could also result in a chronic or long-term health impact. The Panel members suggested that the terms used to designate time or space of size need to be discussed in relation to size, time, time, and scale of event and then in terms of impact (size, time and scale). The Panel members suggested a proposed solution: add 'event' or 'impact' to all such descriptive terms."

4) *Expanded case studies and prospective studies:*

P. 32, lines 42-43 notes that: "In the future the EPA should continue research on expanded case studies and long-term prospective studies."

- A Panel member noted that: "I believe a finding was that EPA should do the prospective case studies they proposed to do. We should decide if that is our position and be consistent throughout the document on this point."

Chapter 5: Chemical Mixing Step in the Hydraulic Fracturing Water Cycle (Charge Question 3)

1) *Physical/chemical properties of chemicals in HF fluids:*

- p. 37, lines 19-23, note that: "The draft Assessment Report broadly describes the extent of the chemical data record but should be critical of what is not known and the consequences of this uncertainty (e.g., only 453 of the 1076 chemicals identified in hydraulic fracturing fluids have their physical/chemical properties determined). As such, the SAB does not recommend that the EPA make generalizations regarding how chemicals will behave."

  Several Panel members noted that: "In many places in the draft SAB Panel Report there are very specific data citations where it appears the information available is substantially greater than that relied on by EPA, had broader inclusion criteria for source information been used. The draft SAB Panel Report has repeatedly highlighted such deficiencies, yet has made recommendations based on the limited data used rather than a broader data set it has repeatedly encouraged EPA to include.

  In the SAB's draft response to Charge Question 7, the SAB recommends that the EPA should utilize EU REACH and other sources for physical-chemical properties, which include experimental and estimated values. The EPA SAB response on p. 38 should take into consideration the response to Charge Question 7 suggesting to EPA to utilize other sources of information for physical chemical properties before making final conclusions on what data are available."

2) *Need details regarding complexities for many processes described in the EPA's draft Assessment Report:*

- A Panel member suggested including an additional statement to the draft SAB Report noting that the EPA did not include details in its discussion of complexities for many of the processes being described in the EPA's draft Assessment Report's Section 5.8 Fate and Transport discussion. In that discussion, the description of the uncertainties of the subsurface fate and transport are not captured at all. In Section 5.8.2, the draft EPA Assessment Report discusses soil characteristics but there is no discussion of subsurface migration relative to different conditions in the subsurface, such as geology, hydrogeology, heterogeneity, etc.

3) *Impacts of Spills:*

A Panel member commented that "The report should provide more detail on the 'impacts' of spills – with a focus on duration. From my work within the field I have not observed long term

impacts from spills or releases associated with current HFWC activities. It is important to note that durations of impacts could be longer from issues associated with well construction."

Chapter 6: Well Injection Step in the Hydraulic Fracturing Water Cycle (Charge Question 4)

1) *StimPlan Modeling:*

- p. 54, lines 34-36 notes that: "The SAB notes that models such as "StimPlan" have tried to create conditions to allow a fracture to grow to intersect base potable water, and concludes that no model has successfully created such conditions for any realistic scenarios."

  A Panel member noted that: "This may be so, but we should also encourage in an even-handed fashion that abandoned wells of questionable integrity can provide a conduit to freshwater sources. These are plentiful, not routinely characterized, and in many instances not even identified."

2) *Bainbridge OH and Kildeer ND Case Studies:*

- p. 56, lines 40-45, and p. 57, lines 1-2 note that: "The EPA should include a discussion within Chapter 6 on the strengths and weaknesses of available case studies for well injection activities. The EPA should clarify known data, inferences, and the success of remedial activities that may have occurred associated with these case studies. The EPA describes two case studies in the chapter: Bainbridge, OH (which was a cement failure and not related to hydraulic fracturing injection) (Bair, E.S., et al., 2010); and Kildeer, ND (which was a blowout that happened coincidentally, but was not related to hydraulic fracturing injection) (Battelle, 2013). While these cases are interesting and tangentially relevant, these cases are not directly related to the hydraulic fracturing injection process."

  A Panel member noted that: "I disagree with repeatedly making this distinction so as to seemingly diminish the importance of environmental consequences that have occurred. This study is about impacts on the hydraulic fracturing water cycle broadly written, not one small aspect of this process that occurs over a short period of time."

3) *Background Monitoring:*

- p. 57, lines 18-25 notes that: "The EPA should assess and describe background/baseline or pre-drilling activity water quality data measurements that have been collected in order to better understand scenarios where impacts have been indicated. The SAB notes that this information is important to understand since it provides a baseline reference on what was in the water surrounding hydraulic fracturing sites before human intervention occurred. The State of Colorado is now requiring sampling and measurement prior to and after all oil and gas drilling activity (State of Colorado, 2014). The EPA should describe best management practices associated with the well injection stage of the HFWC within

Chapter 6, and cite the State of Colorado sampling and measurement requirements within this discussion."

A Panel member noted that: "Baseline sampling is mentioned a number of times in the EPA report (and in this draft SAB report). Somewhere in our more detailed comments, we ought to note that doing it right / effectively is more difficult than one might think. We should point that out, in an appropriate place (perhaps on p. 72, which addresses this in a bit more detail). Perhaps we should also recommend to EPA that they should summarize and evaluate existing baseline monitoring efforts, discuss what data need to be collected for such programs to be useful / effective, and identify information gaps that prospective studies could help fill, e.g., by demonstrating what data needs to be collected to identify sources of contamination."

Another Panel member noted that: "The following website discusses the requirements of several states, and more generally the strategies that those states have taken to encouraging the collection of baseline data, which in some states differ from the approach of Colorado. For instance, some states have a rebuttable presumption that contamination of a domestic well within half a mile of a gas well is caused by the development of the well. The scarcity of baseline data is mentioned as a limitation in EPA's draft Assessment, at least in the Executive Summary, but the steps that these states have taken to require or encourage baseline data collection are not; they should be both described and promoted.
http://apps.americanbar.org/litigation/committees/environmental/articles/winter2015-0215-fracking-debate-importance-pre-drill-water-quality-testing.html "

4) Distinction between Flowback and Produced Waters

- P. 62, lines 20-34, note that: "2) The distinction between flowback and produced waters: The SAB questions the importance of distinguishing between hydraulic fracturing flowback and hydraulic fracturing produced water, and recommends that the agency reconsider its decision to distinguish between these waters within the draft Assessment Report. Assuming the agency decides to carry forth the distinction between these waters into the final Assessment Report, the SAB recommends that the EPA condense the text describing the differences between flowback and produced waters as the distinction is somewhat arbitrary in the context of unconventional wells. However, the SAB also recommends that the EPA present additional information on changes in water chemistry over time. While this chapter of the draft Assessment Report distinguishes the terms "flowback" and "produced water" to differentiate the terms in relation to overall well flow, the EPA should more clearly acknowledge that such differentiation is difficult or operational at best. This is important in that releases of produced waters are more likely given the life cycle of a well. Moreover, the EPA should note that produced water more closely resembles formation waters, i.e., produced waters represent pre-existing conditions prior to hydraulic fracturing, whereas in contrast, flowback can include chemicals from injection (production waters generally do not) (Vidic, R.D., et al., 2013; Haluszczak, L.O., et al., 2013; and Balashov, V.N., et al., 2015).

Several Panel members agreed with the following statement from a Panel member: "I thought the EPA's draft Assessment Report did a good job explaining the difference between flowback and produced water, and explained the challenges of distinguishing. The EPA noted that produced water is very different from flowback in terms of composition. From a hazard perspective this difference is important when assessing hazard. If the SAB is saying that it doesn't make sense to distinguish between the two because they are always mixed up in storage ponds and re-use of water, and operationally it's difficult to make a clear distinction, then I would agree it doesn't make sense to distinguish. But if that's not the case, there is an advantage to distinguish between flowback vs. produced water based on the EPA's explanation of the difference in composition."

<u>Chapter 7: Flowback and Produced Water Step in the Hydraulic Fracturing Water Cycle (Charge Question 5)</u>

1) *Seismicity*

- A) P. 64, lines 4-7, note that: "The draft Assessment Report mentions several times in Chapter 4 that pressure cycling of wells can impact cement seals, and the EPA should discuss whether or not these effects on cement seals result in impacts to hydraulic fracturing wastewaters or change the likelihood of leaks as discussed in this chapter."

  A Panel member noted that: "Can seismic activity (e.g., frequent earthquakes having magnitudes in the 2-4 range on the Richter scale, as are being experienced in Oklahoma due to deep-well injection) potentially damage cement seals? If so, shouldn't this also be pointed out here, and also in our comments on Chapter 4 regarding well integrity, and perhaps in the section on "cements and casing" on pp. 49-50?"

2) *Line age and corrosion*

- A) P. 64, lines 10-12, note that: "In addition, since line age and corrosion are factors in developing leaks, the EPA should describe whether leakage rates are smaller for unconventional wells because the hydraulic fracturing facilities are generally newer."

  A Panel member noted that perhaps the following text should be added "… and whether the materials being used today are more or less subject to corrosion, breakage, etc., than those used in the past, i.e., whether material selection is a factor positively or negatively affecting the frequency and volume of leaks and spills."

3) *Long-term effects of Leroy Township, Bradford County, PA event:*

- P. 68, lines 25-28 note that: "Further, within the EPA discussion on the Leroy Township, Bradford County, PA event in the draft Assessment Report, while the EPA described that

localized surface water impacts were reported, the EPA should discuss whether long-term effects were reported for the potable water wells."

A Panel member noted that: "I am not sure how this is possible. We don't know compounds, we don't have analytical methods for some compounds we do know about, routine monitoring of groundwater and surface isn't done, prospective case studies weren't even done."

4) *Data on bromate, chlorate/chlorite, perchlorate or iodate*

- P. 71, lines 23-26 note that: "In addition, the draft Assessment Report does not provide data on bromate, chlorate/chlorite, perchlorate or iodate. All of these chemicals have human toxicity endpoints and some have MCLs, and the EPA should describe in the draft Assessment Report whether these compounds are ever found in hydraulic fracturing waters."

  A Panel member noted that: "As noted in the earlier comments on Ch. 7, EPA should determine if these chemicals are ever found in flowback or produced water. If so, they also ought to determine if they are ever used to prepare hydraulic fracturing fluids (Ch. 5) and if the concentrations change during treatment (Ch. 8). In Ch. 8, our concerns are: 1) if present, are these compounds removed during treatment, and by which processes; and 2) are they formed during treatment. This needs to be sorted out and clearly described, on our part."

5) *Discussion on halogens*

- P. 71, lines 27-28 note that: "The SAB finds that the EPA's discussion on halogens in the report, which is mostly limited to chloride, to be inadequate."

  A Panel member noted that: "This last sentence is not correct and appears to be a misinterpretation of what Writing Team 6 said at the end of a lengthy paragraph on various aspects of halogen chemistry. EPA's report discusses bromide extensively, and to a lesser extent iodide, but primarily in relation to brominated THMs and HAAs, largely ignoring formation of bromate, NDMA, and other halogenated byproducts, as well as chlorine demand. Our comment at the end of the paragraph was that, overall, EPA's handling (discussion) of halogens in the report, with the exception of chloride, is inadequate. It is not true that their discussion was limited to chloride."

6) *Discussion on natural brine movement in the subsurface:*

- P. 72, lines 13-25 note that: "The EPA should also explain in the chapter that there can be natural pathways of brines to the surface, that these natural pathways are not necessarily related to shale gas development, and that brine salts can contaminate aquifers and surface waters naturally. The SAB notes that this complicates the EPA's interpretation of spilled liquids and leaks of flowback and production waters because the background conditions can be marked by the same salts that influence the composition of flowback

and produced waters. The SAB notes that the presence of natural brines from depth that move to the surface or to shallow groundwater is especially important since there is significant public concern regarding the transport of hydraulic fracturing fluid from the deep subsurface of unconventional gas reservoirs to groundwater or surface water. While the potential and rate of such transport may be very low in the context of shale gas development, the SAB recommends that the EPA discuss this pathway and mechanism of brine movement in this chapter in the context of natural brines. The EPA should also discuss whether the presence of shallow brines implies transport upward from depth or not, and if yes, what implications, if any, does this transport have for injected fluids during hydraulic fracturing.

A Panel member noted that: "I find this discussion confusing. Brines are denser than water. Their movement upward will thus be unstable. Yes some diffusion can occur but this process is slow, slower than molecular diffusion of a dilute system."

7) *Description of microbial processes regarding adsorption, absorption and precipitation of HF chemicals:*

- P. 74, lines 2-7 note that: "The SAB recommends that the EPA further describe microbial processes within the discussion on adsorption, absorption, and precipitation on line 26 of page 7-42 of the draft Assessment Report. The EPA used the EPI Suite model to estimate various properties of hydraulic fracturing chemicals. EPI Suite is a group of models that employ some parameters that are uncertain and require detailed sensitivity analysis to assess whether the model provides meaningful results."

  A Panel member noted that: "The situation would seem to be that many compounds are used in hydraulic fracturing, some disclosed and some not; these compounds, and those included in flowback and produced water occupy a wide spectrum of physiochemical properties and in many cases pose analytical problems. Yes many biogeochemical processes are operative. Most hydraulic fracturing solution contain a biocide. For sure there are gaps in the understanding of microbial processes, but lots of other gaps too."

<u>Chapter 9: Chemicals Used or Present in Hydraulic Fracturing Fluids (Charge Question 7)</u>

1) *Toxicity Data Availability*

P. 96, lines 45-46 and p. 97, lines 1-2 note that: "The draft Assessment Report should explicitly indicate what fraction of the compounds identified in hydraulic fracturing fluid and/or produced waters have some hazard information (e.g., any governmental reviewed toxicity data used for risk assessment), and what fraction have no available information."

- A Panel member noted that: "In response to Charge Question 7 we should not limit data to government sources or government peer review. This could eliminate data from OECD and NGO's." The Panel member suggested that the above parenthetical be changed to

read as follows: "(e.g., any data generated or used by State, national, and international non-governmental organizations for risk assessment purposes)".

- Several Panel members suggested changing the parenthetical clause to read as follows: "(e.g., toxicity data available from or used by U.S. or state governments or international non-governmental organizations used for risk assessment purposes, or publicly available peer-reviewed data)".

2) Threshold of Toxicological Concern

In the draft Report's response to Charge Question 7, p. 98, lines 7-11 note that: "EPA should also directly consider and include exposure, use of threshold-of-toxicological-concern concepts, and use of best practices for mitigation of hazards identified in the course of the analysis (e.g., recent information from FracFocus 3 and other sources on trends in substitution of less hazardous chemicals, as well as containment practices), should be addressed to the extent feasible or be noted as gaps in the draft Assessment Report."

- Several Panel members noted that: "While the SAB Panel mentions application of 'Threshold of Toxicological Concern' (TTC), the SAB Panel does not suggest how this could be employed. We should discuss this in particular for flowback and produced water. Based on the amount of HF chemical used in the HF process, and considering the volume into which it would be diluted in flowback and produced water, compounds calculated as present at concentrations below the TTC could be deprioritized from concern as contaminants in these fluids. High dilution of contaminants in these produced waters would minimize potential risk as impacts to drinking water. This could focus any recommended analysis to compounds that at least have the potential to be present at potentially concerning levels."

3) Toxicity Data Availability

- P. 101, lines 6-12 note that: "In addition, while the draft Assessment Report briefly described the ACToR database in Chapter 9, the agency should fully utilize the in vivo toxicology and physicochemical data available through ACToR, including acute, short-term, and chronic toxicity data, data on corrosivity, and experimental physicochemical data. The physicochemical data (e.g., K_{ow}) are not only useful for predicting toxicant fate and transport in drinking water resources, but also can contribute toward evaluating the ability of a compound to cross cell membranes, which is relevant for predicting toxicity."

  Several Panel members noted that: "The EPA is encouraged to use the limited information available to their HF deliberations while recognizing that data such as chemical/physical data on chemicals may only provide suggestions on bioavailability, lipid solubility, and potential for exposure. Such data can be used to identify possible exposure boundaries that will allow the agency to prioritize chemicals that are more likely to have contact and do harm.

An additional reference (citation below) has been added for the EPA's consideration which shows the use of chemical/physical factors in reviewing HF chemicals. The use of Log P reaffirms the need to use available data, limited though it maybe to begin to a better but limited understanding of these chemicals.

Elliot, Elise G., A.S. Ettinger, B.P. Leaderer, M.B. Bracken, and N.C. Deziel. A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. 2016. *Jrnl. of Exp. Sci. and Env. Epi.* Advance online publication, 6 January 2016; doi:10.1038/jes.2015.81."

Appendix 1: Areas of Draft Panel Report that Provide General Advice and Could Potentially Be Supported with Specific Advice

Note from David Dzombak: In the draft Panel report, several comments appear to provide general advice that could perhaps be bolstered with specific advice or suggestions from the Panel on how the EPA could or should address the issue (e.g., by reviewing specific data sources or gathering other specific information). Specific areas of the draft response to charge questions that could potentially be bolstered with specific advice are noted below.

The Panel's draft report has been posted onto the SAB's February 1, 2016 teleconference website at: http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/5fca4c1a644cdc8085257f17006e7272!OpenDocument&Date=2016-02-01 Page and line references noted below refer to the page and line number of the Panel's January 7, 2016 draft report that is available on the above-noted website.

Chapter 4: Water Acquisition Stage in the Hydraulic Fracturing Water Cycle (Charge Question 2)

- p. 33, lines 41-44: Provide possible data sources that would provide information on well completion reports, permit applications, water management plans, and site-specific information on water use and cumulative water withdrawals.

Chapter 5: Chemical Mixing Stage in the Hydraulic Fracturing Water Cycle (Charge Question 3)

- p. 42, lines 21-24: Provide possible data sources that would provide information on failure rates of HF fluid handling equipment.

- p. 43, lines 5-7: Provide possible data sources that would provide information on specifications for monitoring requirements.

- p. 43, lines 16-17: Provide possible data sources that would provide information on equipment failure rates.

- p. 43, lines 22-23: Provide possible data sources that would provide information on spill volumes and frequency of spills.

- p. 43, lines 24-26: Provide possible data sources that would provide information on HF chemical additives.

- p. 43, lines 37-39: Provide possible data sources that would provide information on existing databases from operations analogous to HF that would provide information on chemical mixing and delivery operations that fail and lead to spills.

Chapter 6: Well Injection Stage in the Hydraulic Fracturing Water Cycle (Charge Question 4)

- p. 47, lines 4-7: Provide possible data sources that would provide information on changes and improvements in hydraulic fracturing operations.

- p. 47, lines 15-16: Provide possible data sources that would provide information on DOE data and reports

- p. 48, lines 17-19: Provide possible data sources that would provide information on HF failure mechanisms and frequency of occurrence.

- p. 48, lines 21-24: Provide possible data sources that would provide information on recent State HF regulatory requirements (e.g., which specific States?).

- p. 48, lines 25-26: Provide possible data sources that would provide information on low frequency, high severity HF case studies.

- p. 50, lines 5-11: Provide possible data sources that would provide information on aging HF wells, and re-fractured HF wells.

- p. 50, lines 21-23, p. 52, lines 36-38, and p. 56, lines 13-15: The text requests full statistical analyses on the EPA's Well File Review effort; note the specific statistical analyses that should be conducted.

- p. 50, lines 25-27: Provide possible data sources that would provide information on new HF research and technology since 2010 regarding cements, low thermal gradient setting times, swellable elastomers and flexible cements.

- p. 51, lines 1-4: Provide possible data sources that would provide information on temporal and spatial variations in gas release incidences.

- p. 51, lines 20-22: Provide possible data sources that would provide information on spatial proximity of HF wells to each other.

- p. 53, lines 2-4: Provide possible data sources that would provide information on frequency of impacts from well injection relative to HF wells.

- p. 54, lines 18-20: Provide possible data sources that would provide information on how fractures grow and whether fractures reach the ground surface.

- p. 56, lines 40-42: Provide possible data sources that would provide information on well injection case studies.

- p. 57, lines 13-14: Provide possible data sources that would provide information on examples of HF casing and cementing issues that have caused gas migration behind pipes.

- p. 57, lines 33-35: Provide possible data sources that would provide information on fate of un-recovered HF fluids.

- p. 57, lines 45-47 and p. 58, lines 1-8: Provide possible data sources that would provide information on new HF well injection technologies.

- p. 58, lines 35-37: Provide possible data sources that would provide information on which State(s) may have information on new HF standards that may lower the frequency and severity of impacts.

<u>Chapter 7: Flowback and Produced Water Stage in the Hydraulic Fracturing Water Cycle (Charge Question 5)</u>

- p. 62, lines 42-44; p. 63, lines 1 and 13-16; and p. 73, lines 3-5 and 24-27: Provide possible data sources that would provide information on chemicals used for HF tracers; HF industry use of tracers; and spilled or leaked tracers.

- p. 63, lines 19-21: Provide possible data sources that would provide information on time needed to hydraulically fracture a well, and time needed for HF flowback to return to the surface of a HF well.

- p. 63, lines 33-36: Provide possible data sources that would provide quantitative information on how much activity is occurring in conventional vs. unconventional HF wells.

- p. 63, lines 36-37: Provide possible data sources that would provide quantitative information on how much wastewater is produced from conventional vs. unconventional wells.

- p. 64, lines 9-10: Provide possible data sources that would provide information on impacts associated with conventional vs. unconventional HF wells.

- p. 64, lines 31-35; p. 71, lines 43-44; and p. 72, lines 4-6: Provide possible data sources that would provide information on best management practices for HF flowback and produced water, and regulatory requirements for secondary containment.

- p. 66, lines 18-20: Provide possible data sources that would provide information on examples of long-distance travel of HF constituents.

- p. 68, lines 29-31: Provide possible data sources that would provide information on timeframes to remediate groundwater once contaminated with chemical constituents.

- p. 68, lines 38-43: Describe the specific statistical analyses that should be conducted on sources of flowback and produced water leaks. Describe statistical tools that EPA should use to assess sparse datasets.

- p. 71, lines 9-11, 15-17 and 21-25: Provide possible data sources that would provide information on levels of bromine, bromate, iodide, chlorate and perchlorate in oil/gas and HF wastewaters associated with different geologic formations where HF is occurring.

- p. 74, lines 3-4 and 12-14: Provide possible data sources that would provide information on how microbial processes may affect subsurface transport of HF chemicals.

<u>Chapter 8: Wastewater Treatment and Waste Disposal Step in the Hydraulic Fracturing Water Cycle (Charge Question 6)</u>

- p. 77, lines 23-24: Provide possible data sources that would provide information on costs of HF water purification technologies.

- p. 77, lines 24-25: Provide possible data sources that would provide information on trends in HF wastewater disposal methods.

- p. 78, lines 4-7: Provide possible data sources that would provide information on how HF spill-contaminated soils, pond sediments, and other media are disposed.

- p. 79, lines 2-4: Provide possible data sources that would provide information on which HF wastes are exempt from RCRA.

- p. 80, lines 1-4: Provide possible data sources that would provide information on concentrations of antiscalants in HF waters.

- p. 84, lines 24-26: Provide possible data sources that would provide information on Centralized Water Treatment Facilities (CWTF) wastewater disposal via deep well injection and reuse.

- p. 84, lines 28-29: Provide possible data sources that would provide information on fate of residuals from zero liquid discharge facilities or reuse facilities.

- p. 86, lines 37-39: Provide possible data sources that would provide information on the formation of disinfection by-products through the presence of naturally occurring organic matter.

- p. 87, lines 1-4: Provide possible data sources that would provide information on HF wastes with high ammonium levels, resulting in the formation of chloramines.

Chapter 9: Chemicals Used or Present in Hydraulic Fracturing Fluids (Charge Question 7)

- p. 100, lines 30-35 and 41-44: Provide possible data sources that would provide information on chemicals unique to HF, and chemicals naturally present in the subsurface that return to the surface in produced water.

Chapter 10: Synthesis of Science on Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, and Executive Summary (Charge Question 8)

- p. 109, lines 38-41: Provide possible data sources that would provide information on HF-related impacts that have occurred.

- p. 108, lines 33-35: Provide possible data sources that would provide information on local-level HF impacts (particularly severe impacts).

- p. 110, lines 37-41: Provide possible data sources that would provide information on situations where HF spills have reached groundwater.