[DATE]

EPA-SAB-10-xxx

Subject: Advisory on EPA's Draft Report on Aquatic Ecosystem Effects of Mountaintop Mining and Valley Fills

Dear Administrator Jackson:

EPA's Office of Research and Development (ORD) requested that the Science Advisory Board (SAB) review the Agency's draft Report entitled "*The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields*" (i.e., Aquatic Ecosystem Effects Report). The draft EPA report assesses the state of the science on the ecological impacts of Mountaintop Mining and Valley Fill (MTM-VF) operations on streams in the Central Appalachian Coal Basin. This basin covers about 12 million acres in West Virginia, Kentucky, Virginia, and Tennessee. The draft EPA report reviews literature relevant to evaluating five potential consequences of MTM-VF operations: 1) impacts on headwater streams; 2) impacts on downstream water quality; 3) impacts on stream ecosystems; 4) the cumulative impacts of multiple mining operations; and 5) effectiveness of mining reclamation and mitigation. The impacts of MTM-VF operations on cultural and aesthetic resources were not included in the review.

The SAB was asked to comment on the assessments and analyses regarding the conceptual diagram, literature review, loss of headwater streams, downstream water quality and stream biota, cumulative ecological impacts, and effectiveness of restoration methods. The enclosed report provides the advice and recommendations of the Panel. The SAB found that the overall approach and scope for the draft EPA report is appropriate and comprehensive. The draft EPA report has characterized many of the potential ecological effects that may occur associated with the loss of headwater streams due to valley fill operations, and acknowledges the limited availability of data on this topic. However, the Panel has made recommendations for improvement of the draft EPA report, some highlighted below, and anticipates that EPA will consider incorporating these recommendations as it moves forward with the report.

- ORD used a conceptual model to formulate the problems relative to MTM-VF consistent with EPA's Ecological Risk Assessment Guidelines. The Panel found the model to be comprehensive and inclusive of most appropriate parameters. However, the Panel suggested some modifications of the conceptual model, placement of the model early in the draft EPA report in order to serve as an organizing tool for the remainder of the document, and use of submodels to highlight different sections.

- The Panel reviewed the literature used as the foundation of the draft EPA report and found it to be fairly thorough and comprehensive, although there were some important omissions. Additional literature was suggested by the Panel for improvement of future drafts of the draft EPA report.

- The Panel believes the draft EPA report's assessment of the impacts regarding the loss of headwater streams should be strengthened by improving the report's discussion of the following issues associated with loss of headwater and forest resources: (1) lack of an estimate of the ultimate area to be affected by MTM-VF over different timeframes; (2) lack of an explicit inventory of the diversity of freshwater habitats affected; (3) lack of depth regarding the loss of biodiversity; and (4) need for improved precision and accuracy in the assessment of the effects of MTM-VF on ecosystem function.

- Regarding the causal linkages between MTM-VF downstream water quality and effects on stream biota, the Panel agrees with the overall conclusions that there is strong evidence for a causal relationship between MTM-VF and downstream water quality. The Panel also agreed with the reliance on field data which strongly supports a causal relationship between MTM-VF and impaired aquatic communities. The Panel recommends that the draft EPA report clarify that total dissolved solids (TDS) and conductivity are relatively coarse indicators of water quality, and that EPA consider developing a more robust characterization of MTM-VF effluents and receiving waters with respect to ionic composition. The Panel also cautions EPA regarding the reliance on acute toxicity tests with non-native surrogate species for inferring consequences of changes in water quality associated with MTM-VF activities. EPA should conduct a formal threshold response analysis for macroinvertebrates and provide further emphasis on effects of selenium on aquatic organisms, due to the preliminary indications of a risk of effects at higher trophic levels in the aquatic community analysis. EPA should also further assess the potential effects of MTM-VF releases on freshwater mussels, salamanders, crayfish, and other aquatic life.

- Regarding cumulative ecological impacts of MTM-VF, the Panel agrees that the published literature on the cumulative ecological impacts of filling headwater streams with mining waste on terrestrial and aquatic ecosystems is sparse. EPA should evaluate cumulative impacts for aquatic ecosystems from at least five perspectives: (i) spatial; (ii) temporal; (iii) river continuum; (iv) food web; and (v) synergistic. The Panel provided details regarding each of these perspectives, and recommends that EPA use both direct and indirect studies related to MTM-VF activities, studies associated with perturbations which differ from MTM-VF but have similar characteristics, as well as similar studies that address other issues (e.g., selenium, ionic strength).

- Finally, the Panel agrees that there is little published information indicating that current restoration and mitigation practices are effective in offsetting surface mine impacts to streams. The Panel provided suggestions for improving the draft EPA report's characterization of the effectiveness of currently employed restoration methods including: (i) the need to relate current limitations to historic progress; (ii) the need to define restoration in the context of improvement of impacted locations; and (iii) the need to relate restoration to both on-site reclamation and off-site mitigation.

The SAB appreciates the opportunity to provide EPA with advice on this important subject. We look forward to receiving the Agency's response and potential future discussions with the Agency.

Sincerely,

Dr. Deborah L. Swackhamer, Chair	Dr. Duncan Patten, Chair
EPA Science Advisory Board	SAB Mountaintop Mining Panel

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AMD	Acid Mine Drainage
Ca	Calcium
CWA	Clean Water Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Tricoptera
HCO_3	Bicarbonate
LDOM	Labile dissolved organic matter
Mg	Magnesium
MTM-VF	Mountaintop Mining and Valley Fill
ORD	EPA Office of Research and Development
SAB	EPA Science Advisory Board
Se	Selenium
SMCRA	Federal Surface Mining Control and Reclamation Act of 1977
SO_4	Sulfate
TDS	Total Dissolved Solids
µS/cm	MicroSiemens per centimeter
USGS	U.S. Geological Survey

1. EXECUTIVE SUMMARY

EPA's Office of Research and Development (ORD) requested that the Science Advisory Board (SAB) review the Agency's draft Reports entitled "*The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields*" and "*A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams*." These draft EPA reports were developed by ORD's National Center for Environmental Assessment upon the request of EPA's Office of Water and Regions 3, 4, and 5, and help provide scientific information to support EPA's actions on environmental permitting requirements related to Appalachian surface coal mining operations.

This SAB Advisory focuses on EPA's draft Aquatic Ecosystem Effects Report. EPA requested that the SAB comment on various aspects of the Aquatic Ecosystem Effects Report, including the draft EPA report's assessments and analyses regarding the conceptual diagram, literature review, loss of headwater streams, downstream water quality and stream biota, cumulative ecological impacts, and effectiveness of restoration methods. The enclosed advisory report provides the advice and recommendations of the Panel regarding the draft EPA report.

In general, the SAB found that EPA's overall approach and scope for the draft EPA report is appropriate and comprehensive. Several areas, however, can be enhanced and focused. While a more detailed description of the technical recommendations is described in the draft EPA report, the key points and recommendations are highlighted below.

<u>Conceptual Diagram</u>

The draft EPA report uses a conceptual model to formulate the problem, and EPA requested the SAB to comment on whether the model included the key direct and indirect ecological effects of MTM-VF. Overall, the Panel considered the conceptual diagram to be comprehensive and relatively complete regarding direct consequences of MTM-VF. Whether any parts of the conceptual diagram addressed indirect consequences of MTM-VF is unclear, and EPA should consider clarifying the text of the report and diagram regarding specific indirect consequences of MTM-VF.

Several suggestions were provided by the Panel for additional components to be added to the diagram:

- Impacts resulting from loss or alteration of upland and riparian systems;
- Activities and outcomes of the reclamation process;
- Additional metrics to represent functional endpoints (e.g., impacts on functional aspects of stream ecosystems);
- Hyporheic zone modification and resulting impacts;
- Recognition of importance of antecedent geologic conditions;

- Additional modifying factors such as geology, landscape context (e.g., rain shadow), and potential biological productivity in streams; and
- The component on metals and especially selenium (Se) contained inaccuracies (e.g. no connection to the food web for Se).

The Panel recommends that a conceptual model be placed near the beginning of the draft EPA report and used as an organizing tool for the remainder of the document. The Panel suggests that distinct sub-components of the diagram representing the dominant activities and resulting impacts be incorporated into each section of the text where appropriate. The Panel also believes the causal diagram should depict levels of uncertainty.

Additional suggestions for improving the model include for example: clarifying directionality of impacts indicated in the diagram; review whether directionality of impact or a change " Δ" in the model is warranted; clarifying use of stressor and response variables; and connection of the many hydrological variables in the model.

<u>Literature Review</u>

ORD requested SAB to consider whether the draft EPA report includes the most relevant peer-reviewed, published literature on this topic. In general, the Panel believes the draft EPA report includes much of the key literature available at the time the draft EPA report was written related to MTM-VF within the bounds defined by EPA for the draft EPA report. Several suggestions were provided by the Panel for improving the literature base for the draft EPA report (e.g., literature on Se, impacted biota other than aquatic macroinvertebrates, and stream conductivity). Headwater streams should be better defined through citations to available literature, and clarification provided regarding the degree that that literature and supporting data are related to ephemeral, intermittent or perennial streams. This relates to accurate accounting of miles of ephemeral vs. intermittent vs. perennial streams. Additional references that should be considered are included within Appendix 1.

<u>Loss of Headwater Streams</u>

ORD requested the SAB to comment on whether the draft EPA report appropriately characterized the ecological effects of the loss of headwater streams. The Panel believes the draft EPA report has characterized most of the potential ecological effects that may occur associated with the loss of headwater streams due to valley fill operations, and acknowledged the limited available data on this topic. However, EPA's assessment of the impacts regarding the loss of headwater streams can be strengthened by improving the discussion on the following issues associated with loss of headwater and forest resources: 1) lack of estimate of ultimate areas to be affected by MTM-VF over different timeframes, 2) lack of an explicit inventory of the diversity of freshwater habitats affected, 3) lack of depth to the assessment of the loss of biodiversity, and 4) need for improved precision and accuracy in assessment of effects of MTM-VF on ecosystem function. The degree to which ephemeral and intermittent headwater streams have been adequately mapped by traditional data sources (e.g., U.S. Geological Survey topographic maps) limits the usefulness of the cumulative impacts assessment.

<u>Downstream Water Quality and Stream Biota</u>

ORD requested the SAB comment on the causal linkages between MTM-VF, downstream water quality and effects on stream biota. With a few important caveats, the Panel agrees with EPA's overall conclusions that there is strong evidence for a causal relationship between MTM-VF and downstream water quality. The draft EPA report links these changes in water quality to benthic communities, and the evidence assessed from various studies showing changes in ion concentrations associated with MTM-VF is very compelling. Several suggestions were provided by the Panel for improving the discussion on causal linkages between MTM-VF downstream water quality and effects on riparian and stream biota and functions.

Regarding the use of conductivity as a surrogate stressor, the Panel recommends that the draft EPA report should acknowledge that measures such as total dissolved solids (TDS) or conductivity are relatively coarse indicators of water quality because the relative toxicity of cations and anions varies greatly. Although conductivity provides an integrated measure of major cations and anions that may cause stress, EPA should consider developing a more robust characterization of MTM-VF effluents with respect to ionic composition, including an analysis that exploring the role of the matrix ions as well as trace constituents, since it would improve the mechanistic understanding of toxicological effects associated with releases from MTM-VF activities.

The Panel identified several limitations of laboratory toxicity tests, and generally agreed that the field data provided strong support for a causal relationship between MTM-VF and impaired aquatic communities. Inferences from field data combined with available information on how TDS increases downstream from MTM-VF strongly support EPA's conclusions. The draft EPA report should provide further emphasis on the effects of Se on aquatic organisms and additional information on the potential effects of MTM-VF releases on freshwater mussels, salamanders, crayfish, and other aquatic life. EPA should further consider the potential impacts of disturbances other than MTM-VF in the region. It would also be useful to conduct a formal threshold analysis on macroinvertebrate sensitivity to MTM-VF releases, including an analysis of the effects on Ephemeroptera (mayflies) relative to other macroinvertabrates. The Panel also made specific suggestions regarding other analyses that would enhance the basis of the draft EPA report's conclusions. EPA should consider using direct measurements of functional feeding groups to assess stream function, assess MTM-VF effects on downstream hydrology, and provide a deeper discussion of the relationship among headwater streams, MTM-VF operations, and mitigation as related to hyporheic communities.

Cumulative Ecological Impacts

ORD requested the SAB to comment on whether the draft EPA report accurately describes the state of knowledge on cumulative ecological impacts of MTM-VF. The Panel agrees with EPA that the published literature is sparse with regard to the cumulative ecological impacts on terrestrial and aquatic ecosystems of filling headwater streams with mining overburden. The Panel's comments primarily focus on definitions and the framing of issues covered within the draft EPA report. Perhaps EPA could conduct an enhanced, more productive effort to find or generate relevant information which addresses the cumulative effects aspect of the topics covered within this report. The search for data for use in evaluating the extent (spatial and temporal) and significance of cumulative impacts can and should involve both direct and indirect (peer reviewed papers of studies designed for a different purpose) studies related to MTM-VF activities as well as those associated with perturbations which differ from MTM-VF but have similar characteristics. Aquatic ecosystem cumulative impacts should be evaluated from at least five perspectives: (i) spatial; (ii) temporal; (iii) river continuum; (iv) food web; and (v) synergistic. The Panel provided details regarding each of these perspectives, and included suggestions for further assessing these perspectives:

- Spatial perspectives: EPA should gather relevant information to consider potential spatial effects. From this perspective, relevant information would be any detailed physical, chemical, or biological stream data at (or near) two or more of the MTM-VF operations within a given watershed as well as two or more points in the drainage downstream from all the point source operations. EPA should also gather and assess relevant information on the area and volume of earth movement associated with MTM-VF operations, the percent change in vegetation (e.g., land clearing) that has occurred in a watershed from these operations based on pre-mine vs. post-mine land use, and the proximity of these activities to the streams.
- Temporal perspectives: EPA should assess data collected before, during, and after one or more MTM-VF operations within a given watershed, with the emphasis on a time series of measurements taken both "before" and "after" for a given parameter.
- River continuum perspectives: EPA should consider modeling the production, downstream routing, and reutilization of organic matter or nutrients; more closely consider cumulative impacts on flow paths and residence times of water; and assess whether MTM-VF effects flow and flow regimes downstream and, if so, how such changes affect aquatic life.
- Food web perspectives: EPA should evaluate cumulative food web impacts in published data on community structure, and assess tissue analyses archived or of freshly collected samples of taxa representing certain trophic levels.
- Synergistic perspectives: EPA should consider assessing certain stressors using existing data to help assess whether the impacts associated with MTM-VF interact among stressors associated with mixed land use in the watershed. EPA should also assess whether

potential bioaccumulative effects to the food web appear to be additive or multiplicative, or linear or non-linear.

The Panel also suggests that EPA consider both positive and negative cumulative impacts (e.g., fragmentation from multiple forest losses) associated with new, altered terrestrial ecosystems within the analysis.

<u>Effectiveness of Restoration Methods</u>

ORD also requested the SAB to comment on whether the draft EPA report appropriately characterizes the effectiveness of currently employed restoration methods. In response, the Panel agrees with EPA's contention that there is little published evidence that current restoration approaches are effective in recovering aquatic ecosystem functions that have been lost as a result of MTM-VF. However, there are several important issues relating to, for example, the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA), off and on site activities, hydrologic processes and aquatic resources that should be addressed further. The Panel recommends that EPA should:

- Define "restoration" within the context of related terms such as reclamation, rehabilitation, enhancement, and mitigation.
- Delineate the scope of restoration as it relates to the SMCRA requirements (focus solely on restoration of aquatic functions? or terrestrial functions as well?).
- Define the interaction between hydrologic processes and terrestrial restoration, in as much as groundwater is an important component of both intermittent and perennial stream functions.
- Restate the central question as: "To what extent has it been shown that on-site reclamation and off-site mitigation as currently practiced are effective in restoring aquatic ecosystem functions that are impacted as a result of MTM-VF?"
- Define the spatio-temporal scales of interest as they relate to restoration (e.g., local stream segment vs. whole watershed; active vs. post-mining; near-term vs. long-term benefits).
- Organize the section on restoration under two major subheadings: "On-Site Reclamation" and "Off-Site Mitigation."
- Fully consider progress that has been made in surface mine reclamation since SMCRA enactment (especially as it relates to reforestation, soil development, slope stability, storm water management, and reductions in sediment runoff and acid mine drainage).
- Identify important shortcomings in current reclamation practices as they relate to aquatic resources.
- Discuss the potential for improved reclamation practices to meet objectives for aquatic resources.
- Address upland/terrestrial objectives of reclamation, or make a stronger argument for why consideration of this topic is outside the scope of the draft EPA report recognizing the

impact that upland reclamation has on groundwater infiltration as well as fluvial processes.

2. BACKGROUND

EPA's Office of Research and Development (ORD) requested that the Science Advisory Board (SAB) review the Agency's draft Reports entitled "*The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields*" (draft EPA report) and "*A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams*." The reports were developed by ORD's National Center for Environmental Assessment at the request of EPA's Office of Water (OW) and Regions 3, 4, and 5, and provide scientific information to support EPA's actions on environmental permitting requirements for Appalachian surface coal mining operations.

The Panel met on July 20-22, 2010 to review and provide advice to ORD on the scientific adequacy, suitability and appropriateness of the two ORD reports. The Panel reviewed the draft EPA reports and background materials provided by ORD, and considered public comments and oral statements that were received. The Panel's advice is provided in two SAB Advisory Reports. The present SAB Advisory document provides advice on the Aquatic Ecosystem Effects Report. A companion SAB Advisory document discusses the draft Conductivity Benchmark Report.

The information in the draft Aquatic Ecosystem Effects Report will assist OW and the Regions to support EPA's actions on environmental permitting requirements for Appalachian surface coal mining projects, in coordination with federal and state regulatory agencies. Using the best available science and applying existing legal requirements, EPA issued comprehensive guidance on April 1, 2010 that sets benchmarks for preventing significant and irreversible damage to Appalachian watersheds at risk from mining activities.

EPA requested that the SAB respond to six charge questions associated with SAB's review of the draft Aquatic Effects Report. The six charge questions associated with the draft Aquatic Effects Report are discussed below, and the June 10, 2010 memorandum is provided as Appendix 2 to this Advisory Report. The cover letter in this Advisory Report highlights the outcome of the SAB's deliberations and recommendations, and the Response to the Charge Questions below provides details regarding these recommendations.

In this Advisory Report there often appears to be repetitive responses to Charge Questions. In some cases, similar topics are discussed under more than one Charge Question. This results from both the integrated nature of the draft EPA Report and an overlap in interpretation of the Charge Questions. The Panel's responses to the Charge Questions vary in length and detail. This is a consequence of both the importance of the response and the amount of necessary material required to respond comprehensively.

3. EPA's Charge to the SAB Panel Selected to Review the Draft EPA report on Aquatic Ecosystem Effects of Mountaintop Mining and Valley Fills

Background

EPA's Office of Research and Development (ORD) prepared the draft EPA report entitled "The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields." The purpose of the report is to assess the state of the science on the ecological impacts of Mountaintop Mining and Valley Fill (MTM-VF) operations on streams in the Central Appalachian Coal Basin. This basin covers about 12 million acres in West Virginia, Kentucky, Virginia, and Tennessee. The draft EPA report reviews literature relevant to evaluating five potential consequences of MTM-VF operations: 1) impacts on headwater streams; 2) impacts on downstream water quality; 3) impacts on stream ecosystems; 4) the cumulative impacts of multiple mining operations; and 5) effectiveness of mining reclamation and mitigation. The impacts of MTM-VF operations on cultural and aesthetic resources were not included in the review. EPA used two primary sources of information for the evaluation: (1) the peer reviewed, published literature and (2) the federal Programmatic Environmental Impact Statement (PEIS) on Mountaintop Mining/Valley Fills in Appalachia and its associated appendices prepared in draft in 2003 and finalized in 2005.

On June 10, 2010, EPA sent the following six charge questions to the SAB to respond to regarding its review of the Aquatic Effects report. The complete June 10, 2010 memorandum from EPA to the EPA SAB Staff Office is provided as Appendix 2 to this report.

Specific Charge Questions addressed in the Review of the Draft EPA report on Aquatic Ecosystem Effects of Mountaintop Mining and Valley Fills

Charge Question 1: The Mountaintop Mining Assessment uses a conceptual model (Figure 12 of the draft document) to formulate the problem consistent with EPA's Ecological Risk Assessment Guidelines. Does the conceptual diagram include the key direct and indirect ecological effects of MTM-VF? If not, please indicate the effects or pathways that are missing or need additional elucidation.

Charge Question 2: This report relied solely on peer-reviewed, published literature and the 2005 Final Programmatic Environmental Impact Assessment on Mountaintop Mining/Valley Fills. Does this assessment report include the most relevant peer-reviewed, published literature on this topic? If not, please indicate which references are missing.

Charge Question 3: Valley fills result in the direct loss of headwater streams. Has the review appropriately characterized the ecological effects of the loss of headwater streams?

Charge Question 4: In addition to impacts on headwater streams, mining and valley fills affect downstream water quality and stream biota. Does the report effectively characterize the causal linkages between MTM-VF, downstream water quality, and effects on stream biota?

Charge Question 5: The published literature is sparse regarding the cumulative ecological impacts of filling headwater streams with mining waste (spoil). Does the review accurately describe the state of knowledge on cumulative ecological impacts of MTM-VF? If not, how can it be improved?

Charge Question 6: The Surface Mining Control and Reclamation Act and its implementing regulations set requirements for ensuring the restoration of lands disturbed by mining through restoring topography, providing for post-mining land use, requiring re-vegetation, and ensuring compliance with the Clean Water Act. Does the review appropriately characterize the effectiveness of currently employed restoration methods?

4. RESPONSE TO THE CHARGE QUESTIONS

4.1. Charge Question 1: The Mountaintop Mining Assessment uses a conceptual model (Figure 12 of the draft document) to formulate the problem consistent with EPA's Ecological Risk Assessment Guidelines. Does the conceptual diagram include the key direct and indirect ecological effects of MTM-VF? If not, please indicate the effects or pathways that are missing or need additional elucidation.

General Comments

The Panel engaged in a thoughtful and vigorous discussion about the conceptual diagram. Overall, the conceptual diagram was viewed as being comprehensive and relatively complete regarding direct consequences of MTM-VF. It does not appear that any parts of the conceptual diagram addressed indirect consequences of MTM-VF, and EPA should consider amending the text of the report and diagram to address specific indirect consequences of MTM-VF.

Specific suggestions for additional components to be added to the diagram focused on the following:

1) impacts resulting from loss or alteration of upland and riparian systems were not well-represented on the left side of the diagram;

2) activities and outcomes of the reclamation process were not addressed in the diagram at all (e.g., hyporheic zone modification, potential nutrient runoff from fertilized soils, sediment runoff from unprotected soils, altered flow regime, altered riparian structure and function, and (potentially) conversion from forest to grassland habitat);

3) index of biotic quality is the only endpoint represented in the diagram, and other metrics could potentially be used that better represent functional endpoints (e.g., altered food web and energy flow). Even though data regarding functional endpoints specifically related to mining impacts are not well represented in the literature, substantial recent information about mining and other similar impacts on functional aspects of stream ecosystems are not well represented and could be included in the diagram (e.g., functional links between activities and different components of hydrology such as altered base flow, peak flow, altered flow regime, flood frequency, and subsequent responses);

4) hyporheic zone modification and resulting impacts were not well represented;

5) the importance of antecedent geologic conditions is not adequately recognized;

6) additional modifying factors such as geology, landscape context (e.g., such as rain shadow), and potential biological productivity in streams could be helpful if included in the diagram; and

7) risks to the food web from Se also need to be more clearly differentiated, perhaps in the diagram.

There was agreement within the Panel that the document would benefit from placing the conceptual model near the beginning of the draft EPA report and using it as an organizing tool for the remainder of the document. Within the diagram itself, EPA is encouraged to think about ways to point out what is more important and what is less important. For example, first order impacts (e.g., related to Se or conductivity) should be highlighted, since those were the constituents deemed to have the largest impacts. The conceptual model also should suggest the relative importance of different issues or impacts and how the risks differ (e.g., the risks due to exposure to nickel (Ni) are not the same as those related to Se exposure). Further, near-field and far-field effects could be quite different depending on the flows and their interactions with the hyporheic and riparian zones.

The Panel believes the conceptual diagram is so complex that its utility is somewhat limiting. The style of this conceptual model, and the level of information portrayed, do not clearly portray the potential multi-scale (temporal, spatial) effects of mountaintop mining. Therefore, the diagram should be separated into distinct sub-components representing the dominant activities and resulting impacts, and these be incorporated into each section of the text where appropriate. EPA should then consider providing the complete model as an Appendix, presented in a manner that facilitates viewing (e.g., larger format paper). Also, a pictorial diagram illustrating potential causes and effects, from upland landscapes to streams to downstream effects, may be more effective at conveying the multi-scale, cumulative impacts of an example mining operation.

In addition to the above comments, the causal diagram should depict levels of uncertainty. For example, the diagram should represent topics with substantial data and coherent results versus hypothesized outcomes with less substantiating evidence. Although indirect as well as direct pathways, temporal as well as spatial dimensions, and near-field versus far-field impacts would enhance the utility of the diagram, they might be difficult to depict. These dimensions should be addressed explicitly in the text if they cannot be depicted in the diagram.

Specific Comments

The model is presented in two parts, one for mountaintop removal and one for valley fill, which the Panel believes is an acceptable approach. The removal portion addresses loss of forests, riparian areas, and issues with soil (e.g., bare soil areas, erosion). The valley fill portion indicates only one initial major impact (stream burial). Since valley fills may bury more than just streams, the draft EPA report should discuss concerns associated with the broader riverine system. Also, the model refers to “headwater habitat” loss as an aspect of stream burial. However, in a riverine system, lost habitats include “instream,” riparian. floodplain, and adjacent uplands, and the draft EPA report should clearly distinguish these lost habitats, since headwater taxa decline may be quite different among these components of the riverine system. The type of stream depicted in the diagram (e.g., perennial, ephemeral) should be made clear in the text, and the terminology within the diagram should reflect the language within the text. Where pathways differ for different hydrologic stream types (which should be defined in the text), the stream type should be explicitly identified.

- The draft EPA report should define what is meant by headwater taxa and clarify why headwater taxa are considered differently from other aquatic taxa, amphibians and macroinvertebrates in the diagram. If specific components of the headwater assemblages are impacted by the processes in the model, they should be identified as such and distinguished from "aquatic" taxa in general.

- The directionality of the impacts (by assigning arrows) in the diagram may not be accurate in every case or over all timescales (e.g., variability in an element of water quality, shifting up and down during events or seasons). Text should be added to the caption and narrative indicating that the directionality is considered to be a typical, important, and potential response over average time scales impacted by the operation.

- The use of arrows versus changes ("Δ") should be reviewed, especially for those stressors that have shown increased as well as decreased changes for the few sites from which data are available.

- The draft EPA report should clarify why some processes are stressors and others are response variables. For example, headwater habitat decline is a stressor and stream burial is not (it is a "source"). This is very confusing as one follows the steps in the model. It may be necessary to designate some variables as both response and stressors.

- Hydrological effects: The description of hydrological effects should be improved in both the figure and in the narrative. There are a few components shown in the model, but they are not necessarily connected to each other and the model appears to be incomplete. Baseflow changes are related to valley fill, and stormflow and runoff is related to mountain top removal, and together these influence downstream hydrology. The model should provide a comprehensive output that incorporates these hydrologic influences.
    - The draft EPA report should have a separate section dealing with Hydrologic Impacts and Water Quantity. The topics that should be covered in this section include altered flows, general hydrological issues, groundwater movement, baseflows, surface runoff, and changing watershed water budgets relative to changing watershed size. These hydrological linkages should be clearly presented in the Conceptual Model.
    - It would be helpful if the diagram indicated how changes within the diagram would affect changes to the entire water budget. For example, the diagram should indicate changes that would occur to flow paths and residence times of water in the landscape, both at the site itself (upland, in-stream) and beyond (cumulative downstream effects).

  - The model path from valley fill through infiltration and baseflow from fill should have outputs similar to those following the "water contact with overburden" outputs and not just nutrient responses.
  - The model seems to imply that streams are two dimensional threads which is not an accurate depiction of streams. “Stream burial” as described in the model does not but should explicitly recognize stream drainages as fractal structures whose representation in “typical” maps and databases is limited to perennial and intermittent channels and does not represent many intermittent or ephemeral channels.
- Additional missing model components include:
  - Reclamation: On the first “line” of the diagram, a key human activity which does not appear directly stated and which should be added is reclamation, which is on-going with most mining operations and occurs nearly concurrent with forest clearing and soil stockpiling. Reclamation is more than just replanting; it includes soil removal and stockpiling which would then be linked to regrading and replanting. Reclamation in the context of re-mining should also be included.
  - Stream type or stage: Another element that may impact the ecological effects is the identification of stream type or stage which should be added to the model prior to stream burial (e.g., see N.C. Division of Water Quality, 2005). It is important to recognize the differences between and the subsequent impacts on the various types of streams (e.g., ephemeral, intermittent, and perennial streams). Ephemeral streams flow only following storms. Intermittent streams flow only for a portion of a year - a true intermittent stream, from the standpoint of a characteristic community, must dry completely (i.e., hyporheic habitat is dewatered) during the annual cycle. Perennial streams flow year-round, although flow may at times be restricted to the hyporheic zone and not be visible at the surface.
  - Habitat fragmentation: A significant element that may impact the ecological effects is loss of genetic structure associated with small effective population size causing a decline in amphibians or macroinvertebrates (such losses are in response to valley fill that increases the dispersal distance between headwater populations).
  - Forest clearing impacts: Impacts from forest clearing that should be considered including: a) change in light regime; b) loss of coarse woody debris (in addition to organic matter); c) elimination of nutrient exchange between upland and stream (and back again); and d) impacts to stream subsidies in the form of salamander, crayfish, and insect biomass. These impacts result in increased benthic primary production, a potential shift from heterotrophic to autotrophic processes, reduced organic matter inputs and processing, and food web shifts.
  - Changes in biotic index: With changes in organic matter, light regime, and sedimentation, there will be measured changes in biotic index quality that should be considered (assuming published literature is available for use in the report). This may also result in an observed shift in the food web towards an autotrophic system, which is more heavily dependent upon instream algal production, and a

resulting decrease in the top predators in the system (salamanders and brook trout) that represent a large shift in the structure and function of the ecosystem.
  - Impacts on fauna: Impacts on other fauna (birds and bats) should be acknowledged, especially under situations where headwater riparian zones are lost or situations where Se accumulates up food webs.
  - Sediment loads: Increased sediment loads have wider effects than indicated in the model. For example, an impact resulting from elevated sediment levels that may be added to the model include decreased benthic primary production with attendant impacts on stream metabolism.
  - Impacts on hydrology, landscape pattern, landscape connectivity, and biodiversity: Under scenarios where terrestrial vegetation is replanted as herbaceous cover, rather than forest cover, the impacts on hydrology, landscape pattern (i.e., fragmentation), landscape connectivity, and biodiversity should be addressed in the report and the diagram.

- Since increased nutrient levels have large effects on detrital pathways and primary producers in streams (as indicated in ecosystem-level experiments for Southern Appalachian streams), nutrient level effects on detrital pathways should be considered in the model.

- While it is highly valuable to include life history data for the benthic invertebrates within the model, relatively few data are available.

4.2. Charge Question 2: This report relied solely on peer-reviewed, published literature and the 2005 Final Programmatic Environmental Impact Assessment on Mountaintop Mining/Valley Fills. Does this assessment report include the most relevant peer-reviewed, published literature on this topic? If not, please indicate which references are missing.

4.2.1. General Comments

In general, the draft EPA report includes much of the key literature associated with aquatic ecosystem effects related to MTM-VF that were available at the time the draft EPA report was written within the bounds defined by EPA for the draft EPA report. It would be appropriate to include some local grey literature to help scope some of the issues that are under-represented.

4.2.2. Specific Comments

Some literature references that need to be included or enhanced include:

- Selenium effects on higher trophic levels, as well as references related to the source of the Se would be important. Not all stratagraphic sequences and, therefore, not all valley fills contain Se or will be a source of Se.
- Semi-aquatic and riparian fauna (e.g., salamanders and their diversity; stream-related mammals such as raccoon and mink).
- Mussels and their complex life histories.
- Osmotic stress of aquatic biota.
- Sulfate effects from a soon-to-be-released book from *The National Academies Press* (National Research Council, 2010) on coal bed methane discusses sulfates and effects which could be drawn on for this study.
- Decreased resistance and resilience of populations or communities in the face of multiple stressors (i.e., synergistic effects), because communities already affected by a stressor are more susceptible to additional stressors).
- Sediment and treatment ponds and their downstream impacts. Hydrologic response addressed in the draft EPA report is from traditional reclamation consisting of compacted spoil and grasses. The draft EPA report needs to be expanded to encompass the hydrologic response using the Forest Reclamation Approach which has been widely accepted throughout the surface mining industry. Citations are provided in Appendix 1 for Appalachian Regional Reforestation Initiatives (ARRI) Reports that are prepared by the U. S. Forest Service and U. S. Department of Energy.
- Either the draft EPA report should incorporate stream recovery literature or note that there is a gap in this information

- Literature is available for the study region from the catchment science community which may be useful to improve how to articulate reference conditions. For example, literature that indicates the range of conductivity found in "relatively undisturbed" watersheds of the region that have been monitored long-term; such literature might help indicate further contrasts between them and the paired studies (MTM-VF vs. reference). The draft EPA report focuses on traditional reclamation technology. Reclamation technology has changed and there has been a transition to more environmentally sound reclamation of hydrology, sediment, conductivity that more closely mimic natural forested hydrology after some period of time. References and text should be added to recognize these changes in technology. Citations are included in Appendix 1 that are related to Charge Question 6.
- The Appalachian region as a refuge for organisms during the past glaciation (page 13) because this sets the scene for the assemblage of organisms present today and also the changes that naturally occur with changing climate and other variables.
- The West Virginia gap analysis (page 17).
- Additional references that should be considered and are related to this Charge Question are included within Appendix 1.

4.3. Charge Question 3: Valley fills result in the direct loss of headwater streams. Has the review appropriately characterized the ecological effects of the loss of headwater streams?

4.3.1. General Comments

The Panel believes that the draft EPA report has characterized many of the potential ecological effects that may occur associated with the loss of headwater streams due to valley fill operations, and has acknowledged the limited available data on this topic. However, the assessment of the ecological effects of the loss of headwater streams can be strengthened by improving the draft EPA report's discussion on the following issues associated with loss of headwater and forest resources: 1) lack of estimate of ultimate area to be affected by MTM-VF over different timeframes, 2) lack of an explicit inventory of the diversity of freshwater habitats affected, 3) lack of depth regarding the loss of biodiversity, and 4) need for improved precision and accuracy in assessment of effects of MTM-VF on ecosystem function. Additional topics of potential concern are articulated below the following discussion on the four issues noted above.

4.3.2. Specific Comments

4.3.2.1. Lack of estimate of ultimate area to be affected over different timeframes.

Headwater streams can be classified as ephemeral, intermittent or perennially flowing systems. A clear definition of what a headwater stream is and how much of that literature and supporting data are related to ephemeral, intermittent vs. perennial streams (and related literature) should be provided (see suggested definitions under response to Charge Question 1). This relates to accurate accounting of miles of ephemeral vs. intermittent vs. perennial streams. It would also be helpful if EPA stated which type of stream is being addressed by the literature that is cited. EPA should clarify whether data exist to quantify the miles of each type impacted by MTM-VF. If such data do not exist, EPA should consider modeling these data based on literature values.

Two forms of headwater loss occur due to MTM-VF operations: a) the removal of headwater streams coupled with rearrangement and conversion of the catchments from steep forested catchments to low gradient grassland catchments (in general), and b) the burial of streams. However, as noted above, the report must define "headwater streams" prior to attempting to characterize changes to the ecological effects of the streams. The assessment of the effect of these losses on the ecology of the central Appalachian coalfield region, however, is hindered by the lack of information on the proportion and extent of the landscape that could ultimately be affected by MTM-VF. This information is critical for any realistic assessment of the different approaches to managing the effects of MTM-VF. For example, if MTM-VF will affect 70% of a particular region or geographic area over time, a different strategy and a different regulatory framework would likely be implemented than if MTM-VF will affect 10% of that region or area. As indicated in the draft EPA report, MTM-VF has already resulted in the loss of >2% of river miles in the study region, and an estimate of the potential changes in the remainder of river miles and the associated upland landscape should be added to the revised report. This should be provided in the form of best and worst case (or minimum and maximum mining permit or land disturbance) scenarios. Finally, EPA should discuss whether and how a reasonably acceptable threshold could be determined that would identify the amount of land area or stream length affected by MTM-VF. For example, would 10%, 20%, or possibly 50% of land affected by MTM-VF be ‘acceptable’? Such an assessment should consider the cumulative impacts associated with MTM-VF operations. The assessment should also determine and justify the percentage of what is affected using a definition of order of stream and stream length (based on Figure 7, some fills are already impacting or filling 2nd order streams), assuming the streams noted are perennial streams.

4.3.2.2. Lack of an explicit inventory of the diversity of freshwater habitats affected.

In its current form, the draft EPA report focuses on the loss of stream channels, often reporting this as miles of channel lost. In reality, however, a range of habitats are being changed, each with a characteristic biological community. These include, but are not limited to: seeps, springs, dripping cliff faces, wetlands, temporary pools, and groundwater habitats. The draft EPA report should acknowledge that these habitats are affected by MTM-VF in addition to the stream channel, since these water resources are as critical, if not more critical, as water sources and habitat than streams, and many are refuges for endemic species and offer quite different aquatic habitat than flowing water. The degree to which ephemeral and intermittent headwater streams have been adequately mapped by traditional data sources (e.g., U.S. Geological Survey topographic maps) limits the usefulness of the cumulative impacts assessment.

Also, although this draft EPA report is restricted to freshwater habitats, it is difficult to assess the effects of mining activities on stream habitats without consideration of the close link between upland forest communities and those of the associated freshwater communities (see Nakano et al., 1999; Nakano and Murakami, 2001; and Fausch et al., 2002).

Finally, the treatment of the different types of headwater streams was vague. For example, the distinction between ephemeral, intermittent, and perennial streams as habitats must be strengthened. As suggested under the response to Charge Question 1, ephemeral streams flow only following storms. Intermittent streams flow only for a portion of a year - a true intermittent stream, from the standpoint of a characteristic community, must dry completely (i.e., hyporheic habitat is dewatered) during the annual cycle. Perennial streams flow year-round, although flow may at times be restricted to the hyporheic zone and not be visible at the surface. In the latter case, perennial streams may be misclassified as intermittent leading to confusion about the true structure of intermittent versus perennial stream communities. The majority of literature addressing biotic and functional characteristics of headwater streams is most likely to focus on perennial and intermittent types. Traditional bioassessment is almost exclusively confined to perennial streams. The traditional bioassessment techniques will not work well in intermittent or ephemeral streams, In addition, surveys occurring when flow is absent or very low (e.g., fall) may skew assessment metrics. The imprecise characterization of these stream types has bearing on any regulatory structure that depends on invertebrate community structure as an indicator of habitat quality.

4.3.2.3. Lack of depth regarding the loss of biodiversity.

In its present form the draft EPA report does not adequately assess the effect of biodiversity loss resulting from MTM-VF. Clearly, such an assessment is hampered by the lack of knowledge of the ultimate area that will be affected by MTM-VF over different timeframes, as well as lack of attention to the diversity of certain key groups of aquatic animals (see discussion in Section 4.4.2.5. of this SAB Report**)**. Nonetheless, the region contains a significant level of biodiversity that is imperiled to varying degrees.

- First, although the draft EPA report correctly points out that the central Appalachians contains a level of biodiversity that is of national and global significance, the draft EPA report should discuss the reasons for the implications of losing this biodiversity and importance of preserving this biodiversity. Such explanation is required to make a compelling case for its proper management and protection.

- Second, the draft EPA report does an unsatisfactory job of describing this biodiversity. There is a great deal of information that is readily available from the West Virginia Natural Heritage Database (online) and the Kentucky Department of Fish and Game Species List (online) that summarizes information on the conservation status of freshwater fauna (vertebrates and invertebrates). In addition, information also exists on the conservation status of plants and plant communities in this region (e.g., see Estill, 2001). Sources of information such as these should be summarized to provide some depth as to exactly what is at risk due to mining activities in the central Appalachians.

- Third, some text should address differences in community structure between streams of different sizes. For example, the invertebrate communities of first order streams are radically different from those of third and fourth order streams. This would help readers understand that one "river mile" is not necessarily equivalent to another lost "river mile" in terms of diversity and species affected by mining activities. Since headwater streams represent the vast majority (i.e., between 65-75% of stream miles in a watershed (Leopold et al. 1964), protection of this important habitat is vital.

- Fourth, the draft EPA report should discuss the effect of fragmentation on population viability of stream biota. Upstream headwater reaches that are unaffected by mining may become isolated from other reaches by the contamination of higher order stream channels, resulting in the fragmentation of otherwise continuous populations (see Hughes et al., 2009). Although the information is sparse, some recent research is available on population-level effects concerning the effect of habitat fragmentation on brook trout population viability (see Letcher et al., 2007). Other sources of information that provide background on the population-level effects of stream habitat fragmentation are Fagan (2002a and 2002b). Also, Hughes et al. (2009) addressed some of these issues with respect to the degree of isolation among stream communities.

- Fifth, some assessment of the "recovery" of biodiversity as affected by reclamation is recommended. For example, the conversion of upland central-Appalachian forest to what is essentially prairie grassland with an avifauna that includes quail, indigo bunting, and horned lark results in a dramatic change in community structure, even though biodiversity might be increased from mining sites prior to reclamation. The potential effects of the replacement of central Appalachian mountain communities with assemblages of invasive or non-native species should be acknowledged in the draft EPA report. The Report should discuss the desirability of restoration of native species and ecosystems, and undesirability of loss of native species, as endpoints in reclamation,

4.3.2.4. Improved precision and accuracy in discussion about ecosystem function.

The Panel believes two areas should be focused on regarding this issue.

- First, EPA should be more specific about the types of functions being addressed, along with the characteristics (i.e., types and rates) of the functions under discussion. Statements in the draft EPA report indicate that stream channels, once removed or buried, lose their function. Although this is certainly true for stream channels draining catchments that are physically removed, it is unclear that this is always the case for streams that are buried. While not all functions may be lost in buried streams, a large number of functions are altered, degraded, or eliminated. Once a stream is buried beneath or reconstructed on the surface of valley fill, it may still be collecting and conveying water, although the solutes and the rates of conveyance may differ. Similar to the former streams that they replace, stream channels formed on and buried beneath reconstituted valley fill also export solutes to downstream reaches (which in the case of valley fill channels is indicated by increases in conductivity of downstream reaches otherwise unaffected). Presumably these reconstituted channels also will be sources of export of dissolved other materials to downstream reaches and sites of some biological processes, including microbial production, primary production (in the case of surface channels), and nutrient cycling.

- Second, statements concerning the dependence of downstream macroinvertebrate communities on material and energy exported from upstream tributaries or reaches are unhelpful without accompanying information describing spatial scale (how far an effect on downstream reaches is measureable). Although the concept of the "dependence of downstream communities on the inefficiencies of those upstream" is well entrenched in the literature, studies that have directly and effectively quantified such linkages between macroinvertebrate communities are scarce. There is uncertainty in the actual magnitude of these energetic linkages, but recent data suggest that it can be significant. If statements concerning the effects of upstream communities on the structure and productivity of those downstream are made, the EPA should cite studies that have actually demonstrated a material or energetic link. One such study (Newbold et al, 2002) involves the development of a model that represents production, downstream routing, and reutilization of labile dissolved organic carbon (LDOC). Although estimates vary with assumed parameter values, preliminary results from this study suggest that 1st and 2nd order streams may support approximately 50%, 25%, and 20%, of the LDOC utilization in third, fourth, and fifth-order streams, respectively. Also, the strength of the linkages and the spatial scale associated with upstream-downstream nutrient cycling should be further described within the report.

In summary, the discussion regarding animal community function focuses on changes in community structure which is manifested in an alteration of the relative abundance of different functional feeding groups. EPA should consider whether the report would be improved if it simplified the discussion by focusing on taxonomic structure - which is what is actually measured - rather than on function. In considering this, if EPA decides to link the discussion of community structure and functional feeding groups, EPA should be aware that the link between community structure and some ecosystems processes (e.g., nutrient cycling) is well established in the literature. While direct measures of ecosystem function impacts due to MTM-VF are few, there is some literature that links the impacts on ecosystem structure to functional impacts (see Wallace et al., 2009; Rodriguez-Iturbe, 2000; and Greenwood et al., 2007).

Additional issues that could be further assessed in the draft EPA report include the time scales of the effects (e.g. localized short-term or permanent?) and spatial scales of the effects (e.g., localized or widespread), and finally, how do the effects cascade downstream or affect downstream waters?). In addition, further consideration on the potential impacts from changes in flow due to valley fills and the effects related to type of stream filled (ephemeral, intermittent or perennial) would be helpful, in part because, as discussed earlier, the imprecise characterization of these stream types has bearing on any regulatory structure that depends on invertebrate community structure as an indicator of habitat quality. Of particular concern is the use of Figure 6 which is limited in its usefulness to describe the more complex system.

Regarding ephemeral streams, the first and second paragraphs in section 3.1 are not in agreement. While the literature on the structure, function, and magnitude of the length and temporal dynamics of ephemeral streams is limited, it is clear that these streams do perform various functions including transporting solutes and sediments across the landscape. While the physical removal of a mountain changes the flow of water across the landscape, thereby eliminating some ephemeral channels, ephemeral channels may be established in the newly formed landscape in reclaimed and restored habitats. There is a general lack of data on ephemeral channels, and the report accurately reflects that lack of knowledge. However, particular attention should be paid to characterization and identification of ephemeral streams in order to adequately characterize the ecological impacts of MTM-VF on the bulk transport of solutes and sediments in these streams and what is the downstream impact, if any, of their transformation after MTM-VF.

The draft EPA report would benefit from further discussion and a stronger emphasis on the critical importance between the form of allochthonous inputs and, how they are impacted by MTM-VF, and how, in turn, the types and diversity of invertebrate fauna are impacted.

The draft EPA report states on page 15 that EPA does not know how to measure the incremental effects of small stream loss on downstream functions. This lack of an assessment tool is critical to understanding the effects of MTM/VF. EPA could potentially solve this measurement issue by convening a workshop of experts on eastern forest streams to discuss the topic.

The draft EPA report also refers to small stream tributaries as among the primary factors for runoff control in high gradient watersheds. The draft EPA report should note the important role of these tributaries play in groundwater recharge which in turn maintains baseflow within streams.

The impacts of loss of upland and instream (salamander) habitat was not well-addressed. There is substantial literature available on this topic beginning with Hairston (1949) which addresses the numerical dominance of salamanders in the southern Appalachian Mountains, and Burton and Likens (1975a and 1975b) in Hubbard Brook. Further references are included in Appendix 1.

The loss of some ecosystem functions and services (such as nutrient cycling) were addressed, but some additional information about food webs and the links to nutrient processing could have been addressed more fully. Organic matter processing issues focused exclusively on leaves, but woody debris is also an important constituent of the organic matter pool (see Wallace and Webster et al., 2001).

4.4. Charge Question 4: In addition to impacts on headwater streams, mining and valley fills affect downstream water quality and stream biota. Does the report effectively characterize the causal linkages between MTM-VF, downstream water quality, and effects on stream biota?

4.4.1. General Comments

With a few important caveats, the Panel generally agrees that the draft EPA report provides strong evidence for a causal relationship between MTM-VF and downstream water quality. The draft EPA report also links these changes in water quality to aquatic communities. The evidence from the peer reviewed literature (e.g., Howard et al., 2001; Hartman et al., 2005; Merricks et al., 2007; Pond et al., 2008) showing changes in ion concentrations associated with MTM-VF is very compelling, although limited in the number of sites evaluated. The biological responses, particularly those based on field evidence, show a clear reduction or extirpation of sensitive taxa associated with sites experiencing high ion concentrations. The SAB agrees with the general conclusions of EPA that MTM-VF results in the loss of headwater streams, degrades water quality and negatively impacts aquatic communities. Therefore, most of the comments below are intended to enhance EPA's presentation of the discussion. As with many of the responses to charge questions, these comments especially demonstrate linkages among the important points emphasized in responses in other charge questions.

There was some discussion of the relative importance of mining versus other stressors among members of the Panel. While mining clearly represents the largest impact to the watersheds assessed in the draft EPA report, it is not the only disturbance in the region. For example, the draft EPA report notes that some streams were impacted by residential development, which may interact with MTM-VF to structure aquatic communities. Therefore the impacts of MTM-VF should be interpreted within the context of these other potential stressors. Residential and industrial development should be considered, as well as state and county road building and repair activities. The available data should be mined (if that has not been done to date) to identify a subset of sites where confounding variables such as legacy land use, residential development, and proximity to ponds have been minimized or eliminated before proceeding with an analysis. Potential causal linkages between conductivity and aquatic communities could also be improved by assessing and including discussion on available literature regarding studies conducted within other ecoregions that consider how organisms respond to high TDS effluents in the field. For example, a large field study is currently underway in the Powder River basin, Wyoming, to assess effects of high TDS effluents on stream communities (Peterson et al., 2009).

4.4.2. Specific Comments

4.4.2.1. Use of conductivity as a surrogate stressor

The most consistent changes in water quality downstream from MTM-VF were increases in concentrations of several cations and anions, resulting in significantly elevated TDS and conductivity. Reported concentrations of SO_4^{2-}, HCO_3^-, Ca^{2+} and Mg^{2+}, are approximately 10 times higher downstream of MTM-VF than in reference systems. There was much discussion among the Panel regarding the use of conductivity as a surrogate measure of toxicological effects for the ions that are causing stress. Because the relative toxicity of cations and anions varies greatly (> 10X), the draft EPA report should note that measures such as TDS or conductivity are relatively coarse indicators of water quality. For example, recent experiments conducted by the U.S. Geological Survey (USGS) suggest that bicarbonate (HCO_3^-) is likely the major source of toxicity in high TDS effluents (see Farag et al., 2010).

Although conductivity is an integrated measure of these major cations and anions in surface waters, minor and trace constituents that do not greatly shape conductivity (e.g., dissolved organics, trace metals, minerals such as selenium) may also affect aquatic life. EPA should consider developing a more robust characterization of MTM-VF effluents and their receiving waters with respect to ionic composition, including an analysis that exploring the role of the matrix ions as well as trace constituents, since such an analysis would improve the mechanistic understanding of toxicological effects associated with releases from MTM-VF activities. Variation in relative toxicity of SO_4^{2-}, HCO_3^-, Ca^{2+} and Mg^{2+} is important for the analysis, but it is equally important to emphasize that each of these ions increased significantly downstream of MTM-VF streams (Table 4) relative to the reference stream data provided. To enhance the causal link narrative, biological plausibility needs reinforcement. A mechanistic understanding between conductivity and biological responses could be enhanced by including some of the relevant environmental physiology literature on specific ions and osmotic pressure. Finally, because most of the information on toxicity of major cations and anions are based on single species toxicity tests, a significant information gap exists in understanding of how aquatic communities respond to major ions. Experimental data using sensitive indigenous species or sensitive life stages of these species would strengthen the case for a causal relationship between conductivity and species extirpation. These recommendations are discussed more comprehensively within the Panel's advice as provided in the companion SAB Advisory Report on EPA's draft "*A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams*" report.

Another important consideration with respect to evaluating toxicity of high TDS effluents is the amount of variation in specific ionic composition that occurs spatially or temporally. For example, Merovich et al. (2007) reported that the amount of temporal variation in water quality differed between reference and mined watersheds. Spatial variation in ionic composition among watersheds also will influence responses from MTM-VF operations and is likely a result of differences in soils and underlying geology. Predicting downstream responses to mining will require an understanding of these natural geological conditions. EPA should include information and a figure depicting the percentages of conductivity that are made up by the various matrix ions, and indicate the consistency and/or variability of such matrix ions in surface and groundwaters across the region. The case for conductivity as a surrogate is greatly strengthened if it can be shown that the relative proportion of the constituent ions contributing to conductivity is about the same in stream water sampled downstream of most MTM-VF operations in the region. In that context, it is important that information be presented in the context of the percent of conductivity made up by individual ions, by calculating the equivalent ionic conductance of the each individual matrix ions and their contributions to the overall conductance of the water solution (e.g., following Laxen, 1977, with summary tables presented by Boyd, 2000).

4.4.2.2. Limitations of laboratory toxicity tests

There was considerable discussion on the Panel regarding the usefulness of laboratory toxicity tests for predicting effects of stressors associated with MTM-VF. Much of what is known about toxicity of major ions is based on results of laboratory toxicity tests using surrogate species (*Ceriodaphnia*, fathead minnows). The acute test results are not especially useful for inferring consequences of changes in water quality associated with MTM-VF activities. The test species are not present in the regional area assessed by the draft document, and the abrupt acute exposures do not adequately reflect exposure conditions associated with MTM-VF in this region. Most importantly, the laboratory toxicity tests involved abrupt, unacclimated exposures that likely do not reflect the exposures that occurred near MTM-VF activities. Field exposures that occurred near MTM-VF activities involved time for acclimation to occur. In general, these acute toxicity data seem too sparse and weak to draw any conclusions. The draft EPA report briefly acknowledges the limitations of these tests for assessing effects of TDS and elevated conductivity on benthic macroinvertebrates (e.g., short duration, focus on mortality as an endpoint, non-indigenous species). Also, relatively few data are available regarding life history data for the benthic invertebrates. The draft EPA report should clarify how the limited data affect the statements and conclusions drawn in the report related to benthic invertebrate life histories.

Unfortunately, because of difficulties culturing aquatic insects in the laboratory, information on toxicity of major ions (and other chemicals) on indigenous species is very limited. More importantly, the relatively few laboratory studies conducted with aquatic insects often show these organisms to be considerably more tolerant to various ions or metal salts than would be predictable based on field observations. At least part of this difference results from the focus on relatively large, later instars which are significantly more tolerant than earlier instars. Thus, reconciling differences between laboratory and field studies is a major challenge in hazard assessment of these effluents.

As noted above, the Panel generally agreed that the field data provided strong support for a causal relationship between MTM-VF and impaired aquatic communities. Inferences from field data combined with available information on how TDS increases downstream from MTM-VF are the most convincing in the document. Fish and macroinvertebrate communities below the MTM-VF activities are consistently deemed "poor quality" based on field surveys (see Fulk, F. et al., 2003; Pond, G.J. et al, 2008; and Stauffer and Ferreri, 2002). These results provide support for the hypothesis that MTM-VF is responsible for degradation of aquatic communities and these data could be presented with more confidence.

The Panel also recognizes the inherent limitations of demonstrating causation based exclusively on descriptive studies. Because of the inferential weaknesses of single species toxicity tests described above and the general lack of information on sensitivity of aquatic insects to specific ions, a viable alternative is to conduct field-based microcosm or mesocosm experiments using intact assemblages of macroinvertebrate communities (Clements et al., 2004). These experiments could be employed to quantify species-specific sensitivity to individual ions or to examine interactions among MTM-VF stressors (e.g., elevated conductivity, and metals including Se).

4.4.2.3. Sensitivity of Ephemeroptera to MTM-VF

The draft EPA report notes the sensitivity of mayflies (Ephemeroptera, EPT) to high TDS effluents, a finding that has been frequently observed in studies of heavy metal contamination. It is important to realize that the reported sensitivity of mayflies to elevated TDS is relative to other macroinvertebrate groups (Trichoptera, Diptera, Coleoptera). There is considerable variation in sensitivity to MTM-VF stressors among mayflies, and some genera may be relatively tolerant to elevated TDS and conductivity. Nonetheless, within the aquatic insects, mayflies are the most appropriate group to consider, since mayflies are important in the food webs of most freshwater ecosystems and a mainstay of water quality monitoring programs (and are recognized and appreciated by fly fishermen throughout the world).

The similarity of responses of macroinvertebrate communities to metals and major ions suggests that similar mechanisms may be responsible (e.g., effects on osmoregulation and ionic composition). More importantly, it suggests that the extensive database available on responses of macroinvertebrate communities to trace metals could potentially be used to characterize effects of major ions.

A threshold response of 500 μS/cm was identified by Pond et al. (2008) for mayfly richness and proportion abundance. It would be useful to subject these and other macroinvertebrate field data to a formal threshold analysis to determine if this level is a valid or statistically significant threshold response (Dodds et al., 2010). These analyses would complement results of the species sensitivity distributions reported in EPA's draft "*A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams*" report.

Differences in relative sensitivity among major macroinvertebrates groups demonstrate that some traditional metrics employed to characterize responses of aquatic communities to other stressors may be less effective for high TDS effluents. For example, caddisflies and some stoneflies are relatively tolerant to major ions, a finding often reported for trace metals. Thus, measures such as EPT richness and abundance are less sensitive to water quality changes associated with MTM-VF than measures based on mayflies alone. The tolerance of many caddisflies to high TDS effluents may account for the "mixed effects of mining on EPT aggregate measures" noted on page 47 of the draft EPA report.

Finally, the effects on mayflies should be put into proper perspective for the non-expert reader. For example, while most stream ecologists recognize the important functional role that mayflies play in streams, some readers may not be familiar with this information. It may also be useful to remind readers that because mayflies are highly sensitive to anthropogenic stressors, their abundance and diversity is a useful measure of stream integrity. The recent study by Pond (2010) has a good overview of these issues that could be incorporated into the text of the report.

4.4.2.4. More emphasis on selenium effects

The draft EPA report indicates that selenium concentrations downstream from MTM-VF are significantly elevated above the Chronic Ambient Water Quality Criterion and that levels in fish tissue exceed concentrations toxic to other consumers. Studies from coal mine leachate are moderately useful for inferring potential Se effects, but do not provide definitive evidence. Regardless, Se concentrations could increase risk of mortality and deformities of fish and/or reduce hatching success of birds. Therefore, it would be useful to include data on Se concentrations in macroinvertebrates and the conceptual models might include a food web model showing expected Se transport among trophic levels. The basic concepts of Se dynamics in such environments are published but not recognized in this report (see Luoma and Presser, 2009; and Chapman et al., 2010). Recognition of the important context (recycling in downstream wetlands, accumulation in food webs, extirpation of fish and birds) could be discussed in the context of the environment in question. There should also be citation of the preliminary data that from recent "grey literature" reports prepared by the West Virginia Department of Environmental Protection that show Se in local food webs. Because Se concentrations are likely influenced by local geology, some understanding of underlying geological processes could improve the ability to predict in the degree of Se contamination among watersheds. Also, while the draft EPA report assumes minimal geologic variability within these eco-regions, the differences may profoundly impact the ecological effects and may explain some of the variability observed (see Caruccio et al., 1977).

4.4.2.5. Sensitivity of mussels and other organisms

The draft EPA report does not provide sufficient information on potential effects of MTM-VF operations on the freshwater mussels of the region. The biodiversity of this group is unique on the Cumberland Plateau, with many species often being threatened or endangered species (Layzer et al., 2006). Mussels are generally no more sensitive than other taxa to potential effects of MTM-VF operations. However, mussels are especially sensitive to the changes described in the draft EPA report because they tend to be among the poorest of osmo-ionoregulators (Dillon, 2000). Furthermore, because many freshwater mussels use specific fish hosts for reproduction, the effects of MTM-VF on fish assemblages will likely have indirect effects on mussels. Mussel populations may also be indirectly impacted by sedimentation, degradation of habitat, and alteration of upstream ecosystem functions (i.e., carbon cycling).

The draft EPA report does an excellent job highlighting the unique biodiversity of the southern Appalachian region. However, the potential impacts MTM-VF on some critical groups, particularly salamanders, mussels and crayfish, could be expanded. For example, there is substantial literature available on this topic beginning with Hairston (1949) which addresses the numerical dominance of salamanders in the southern Appalachian Mountains. In particular, the draft EPA report should consider impacts to crayfish species such as burrowing headwater species that do not live in-stream but rather inhabit areas uphill from the streams. Also, the draft EPA report should note that aquatic organisms in streams and rivers further downstream of the valley fill operations such as hellbenders (*Cryptobranchus alleganiensis*) and other amphibians may be especially sensitive to elevated dissolved materials/salinity because they inhabit these waters year round and can be long-lived.

4.4.2.6. Clarification of Soucek papers

The authors should further clarify the discussion on the Soucek papers cited in sections 5.3, 5.4 and 6.4 of the draft EPA report. Results of acute experiments conducted with *Hyalella azteca* may be less relevant because they were conducted in EPA moderately hard reconstituted water, which may not have sufficient chloride to promote healthy cultures (based on personal observations from Dr. David Soucek (University of Illinois – Urbana); Dr. Chris Ingersoll (USGS, Columbia, MO), and Dr. David Mount (EPA, Duluth, MN). These data demonstrate that toxicity tests performed on MTM-VF water or sediment did not include an adequate array of species. In Section 6.4., the draft EPA report should note that the Soucek et al. (2000) paper was a study of acid mine drainage (AMD) and was not designed to investigate effects of elevated conductivity. Finally, a recent paper by Lasier and Hardin (2010) which investigated chronic toxicity of chloride, sulfate and bicarbonate to *Ceriodaphnia dubia* in low and moderate hardness waters should be included in the draft EPA report.

4.4.2.7. Other considerations

4.4.2.7.1. Functional measures. Section 404 of the CWA states that mining permits should "strive for no net loss of aquatic functions." It is difficult to evaluate the success of this requirement given the lack of studies on MTM-VF and ecosystem function. The limited information on ecosystem function downstream from MTM-VF effluents is a significant data gap; however, studies using other stressors with similar responses could be used to fill this data gap. The dependence on functional feeding group analysis to assess stream function is a problem due to insufficient data for some taxa with respect to the functional feeding groups themselves, and the implicit dependence on structural metrics. The draft EPA report would be strengthened by direct measurement of functional measures, or as stated above, data from studies with similar stress profiles, instead of using structural characteristics (e.g., abundance of functional feeding groups) as surrogates for ecosystem processes.

There have been a number of recent presentations at scientific meetings associated with acid mine drainage which demonstrate how loss of stream ecosystem structure translates into loss of some stream ecosystem functions and the ability of the stream to deliver ecosystem services. These studies could strengthen the link between MTM-VF and stream ecosystem impacts. Unfortunately, these studies have yet to reach the peer reviewed literature. Consequently, EPA is encouraged to examine the rich literature on effects of heavy metals associated with hard rock mining on functional measures to support their argument that MTM-VF affects ecosystem processes (e.g., Niyogi et al., 2001; Carlisle and Clements, 2005).

4.4.2.7.2. Hyporheic communities. One component missing in the draft EPA report is a deeper discussion of the relationship among headwater streams, MTM-VF operations, and mitigation as related to hyporheic communities. This could also be further developed and incorporated into the conceptual model. The hyporheos is a critical sub-habitat for benthos, particularly the juvenile stages of aquatic insects. As mining processes or reclamation procedures continue, the hyporheos may be the habitat most affected, thereby affecting the life histories. Further, the sediment sections on sediments in the draft EPA report seems to focus exclusively on the surficial component of the biota (e.g., how transported sediments will influence the biota) rather than a more holistic treatment that includes hyporheic communities.

4.4.2.7.3. Hydrologic alterations. In addition to MTM-VF effects on downstream water quality, the draft EPA report should address effects on downstream hydrology (both its connections to water quality and the physical condition of components of the downstream riverine system). These hydrologic alterations will likely play a critical role in structuring macroinvertebrate communities through alteration of a range of hydrologic characteristics (e.g., change in timing and duration of peak flow and base flow, and flow periodicity).

Additional references that should be considered and are related to this Charge Question are included within Appendix 1.

4.5. Charge Question 5: The published literature is sparse regarding the cumulative ecological impacts of filling headwater streams with mining waste (spoil). Does the review accurately describe the state of knowledge on cumulative ecological impacts of MTM-VF? If not, how can it be improved?

4.5.1. General Comments

The Panel agrees with EPA that the published literature is sparse with regard to the cumulative ecological impacts on terrestrial and aquatic ecosystems of filling headwater streams with mining waste. The Panel's comments focus primarily on definitions and framing of issues covered within the draft report. EPA should conduct an expanded effort to find or generate relevant information that addresses the cumulative effects aspect of the topics covered within the draft report. The search for data to evaluate the extent (spatial and temporal) and significance of cumulative impacts can and should involve both direct (peer reviewed papers designed to test for cumulative effects) and indirect (peer reviewed papers of studies designed for a different purpose) studies related to MTM-VF activities as well as those associated with perturbations which differ from MTM-VF but have similar characteristics.

The Panel proposes that aquatic ecosystem cumulative impacts be evaluated from at least five perspectives: (i) spatial; (ii) temporal; (iii) river continuum; (iv) food-web; and (v) synergistic. Each of these perspectives is described further below. To better understand the context of these recommended perspectives, some background discussion is also provided. MTM-VF operations under review in this document occur in a landscape that was historically old growth forest and is presently mostly second growth forest. In addition, some of the areas have been previously mined, and in such areas current mining represents re-mining efforts. Thus, a forested landscape is the natural ecological setting within which the terrestrial and aquatic ecosystems under consideration have developed and into which MTM-VF operations described in the draft EPA report have been implemented. In the simplest of terms, MTM-VF operations in this region, regardless of scale, involve the deforestation of a significant patch of local interior forest, removal of substrate from the mountaintop and placement into the adjacent headwater stream valley, and revegetation of both the valley fill and the mined area after the coal has been removed. Thus, potential ecological impacts of MTM-VF operations accrue from the loss of interior forest and aquatic habitat and their associated populations/communities of organisms in response to both direct impact of the operations themselves and indirect effects (downwind or downstream) from them. In that context, cumulative impacts: (i) occur when the overall spatial (or temporal) impact is immediately greater (or gradually becomes greater) than the sum of the individual impacts; and (ii) should be evaluated from several different perspectives because of the four dimensional aspects of terrestrial and aquatic ecosystems. For all practical purposes, the term aquatic ecosystem here refers largely to streams and rivers. The four dimensions of ecosystems (vertical, latitudinal, longitudinal and temporal) should be clearly defined in the text of the report.

For evaluating cumulative impacts in streams and rivers, it is assumed that the upstream to downstream nature of flow provides a high degree of ecological interconnectivity and interdependence within the ecosystem. Moreover, this unique characteristic may make streams and rivers more vulnerable (than terrestrial ecosystems) to both the individual and cumulative effects of point and non-point source changes in a given watershed. Thus, potential impacts from upstream watershed activities, both positive (e.g., water and chemical/particulate food inputs, shade, in-stream processing of nutrients and pollutants) and negative (e.g., loss or modification of water/food inputs, shade, addition of pollutants), can and do reverberate in a downstream direction.

To help provide additional relevant literature regarding the cumulative ecological impacts of filling headwater streams with mining waste on terrestrial and aquatic ecosystems, EPA should consider gathering and evaluating data on long-term cumulative impacts on second-order streams within larger watersheds. Cumulative impact knowledge could also potentially be improved by including peer-reviewed symposium papers such as those within the *Proceedings of the American Society of Mining and Reclamation*.

4.5.2. Specific Comments (Aquatic Ecosystems)

The Panel proposes that for aquatic ecosystems, there are at least five perspectives from which to evaluate cumulative impacts:

4.5.2.1. Spatial: Do the downstream effects from a series of repeated MTM-VF's being implemented in a given watershed have a greater overall spatial effect than the sum of their individual effects? What is the comparative impact of downstream cumulative impacts (indirect) versus the individual local impacts? Specifically, is there a threshold of repeated MTM-VF's that – once exceeded – yields significant downstream impacts?

Examples: If MTM-VF reduces summer baseflow in two or more headwater (first or second order) streams in a watershed, does this translate into summer baseflow falling below some critical "minimum flow requirement" in downstream tributaries? If individual MTM-VF operations elevate some pollutant (e.g., selenium) to levels that are significantly above background and have a toxic effect, does the confluence of tributaries carrying this pollution with other, uncontaminated tributaries result in a tributary carrying a toxic load even though there are no MTM-VF operations located on it? If MTM-VF caused slight warming of small individual headwater tributaries, does this accumulate and cause significant warming (i.e., exceeding some threshold) of downstream reaches?

From this perspective, relevant information would be any detailed physical, chemical, or biological stream data at (or near) two or more of the MTM-VF operations within a given watershed as well as two or more points in the drainage downstream from all of the point source operations. From an analytical perspective, it would be relevant to determine if the changes appear to be additive or multiplicative, or linear or non-linear.

In addition, it is important to gather and assess relevant information on the area and volume of earth movement associated with MTM-VF operations, the percentage change in vegetation cover and type that has occurred in a watershed from these operations based on pre-mine vs. post-mine land use, and the proximity of these activities to the streams. The numbers of mining permits and amount of permitted fill area (which has been exceeded in many cases) are not adequate measures of mining activity. EPA should consider conducting or reviewing previously conducted comprehensive remote sensing and air photo interpretation analyses conducted to adequately understand the extent and distribution of valley fill activities. Such information should be publicly available to allow analysis within and across regions.

Relevant information could also be gleaned by analogy from careful mining of data for pollutants not necessarily associate with MTM-VF (e.g., acid mine drainage, watershed urbanization). For example, the cumulative impacts of acid mine drainage (AMD) might be a good analog for MTM-VF induced changes in chemistry such as conductivity. AMD is chemical (rather than biological or physical) in nature, is produced as a point source (similar to MTM-VF) usually in headwater streams, has a distinct signature (pH) which can be readily measured (similar to the readily measured conductivity), is known to be toxic to macroinvertebrates and fish, and is not confounded by certain other factors which can be common in streams (e.g., sediment). There are confounding factors (such as aluminum toxicity) but they are well known and can be factored into the analysis. There are also several geographic regions of the country impacted by AMD drainage. There are studies in most, if not all regions, demonstrating the cumulative impact of AMD. For example, the mainstem of the West branch of the Susquehanna River is significantly impacted by AMD chemistry but most of it represents the cumulative impact of over a thousand miles of AMD impacted headwater streams located significant distances upstream from the mainstem.

EPA should also assess river continuum perspectives and related effects to aquatic life (discussed further below).

4.5.2.2. Temporal: Do the cumulative downstream effects from one or more MTM-VF's being implemented in a given watershed increase with time?

Examples: Does the persistent release of a contaminant (e.g., Se) at low, non-toxic levels from one or more MTM-VF's gradually result in a high level, toxic exposure for downstream ecosystems through processes such as in-stream storage/sequestration, chemical transformation, or bioaccumulation? Do localized reductions in population size for key aquatic species due to stress related to changes in habitat associated with MTM-VF operations set the stage for extirpation of the taxa due to the regional impact of low recruitment from lost genetic structure (inbreeding due to small effective population size), or additional mortality related to random stochastic events (e.g., floods, droughts)? Do elevated, unnatural levels of contaminants, substances, or habitat factors associated with MTM-VF operations gradually decline to natural, quasi-natural, or non-toxic levels due to in-stream biogeochemical transformation and/or processing or other mitigating agents?

From this perspective, relevant information would include quantitative (flow), physical, chemical, or biological parameters collected ideally before, during, and after one or more MTM-VF operations within a given watershed, but with the emphasis on a time series of measurements taken "after" for a given parameter. Although less than ideal, lack of "before and during" operation data is not absolutely prohibitive to this approach for estimating cumulative impacts. Comparison with separate unmined watersheds is not always appropriate. Post operation studies of long lived species such as mussels (which were not included in most MTM-VF effect studies) could be a good source of information in this arena.

Similar to above, relevant information could also be gleaned by analogy from careful mining of cumulative impact data for other non-MTM-VF pollutants (e.g., PCB's, metals, pesticides, pH). For example, the cumulative impacts of DDT, mercury, and other contaminants have been widely studied in aquatic ecosystems.

4.5.2.3. River Continuum: Does the loss of ecosystem function in one or more MTM-VF headwater streams produce a negative telescoping effect on the structure and/or function of larger downstream ecosystems?

It is suspected that an effect may exist, but the Panel is uncertain of the strength of the literature support for this idea. EPA should conduct an additional review of peer-reviewed literature on this topic (not necessarily limited to cumulative impacts associated with MTM-VF) to provide context.

Background: First order streams flowing through forest receive large amounts of particulate organic matter (e.g., leaves, fruits, seeds, flowers, twigs, branches) and dissolved nutrients (nitrogen, phosphorus, and carbon) that fall or wash into them from the terrestrial environment. Most of this "food" material is processed and tied up in the food web, lost through respiration, or exported downstream. Downstream exports from functional headwater streams are substantial (see Fisher and Likens, 1973; and Webster and Meyer, 1997) and these exports support downstream ecosystem processes (see Mulholland and Rosemond, 1992; Cole and Carco, 2001; Kaplan et al., 2008; and Battin et al., 2008). The cumulative impact of removing a large fraction of the headwater streams from a river network is not amenable to experimental examination. However, modeling and mass-balance studies indicate that permanent loss of cumulative exports from several headwater streams could substantially affect the microbial processes and potentially the invertebrate and fish productivity of downstream reaches (see Meyer and Wallace, 2001; Newbold et al., 2002; and Wipli, 2005).

Downstream reaches may hold the greatest number of rare, endangered, and sensitive species as well as sought-after sport fish (e.g., trout and smallmouth bass). Increasing loads of dissolved materials that are not readily reduced in concentration except by dilution would only increase over time with increasing numbers of MTM-VFs. The populations of amphibians are of particular concern related to downstream cumulative impacts, and these species were not assessed in depth in the draft EPA report. Larger streams in the geographic areas addressed by the draft EPA report can harbor populations of Hellbenders (*Cryptobranchus alleganiensis*) which are already in decline and could suffer from increasing salinity.

Examples: Is the amount of downstream microbial production and biomass limited by the lack of downstream transport of labile dissolved organic matter (LDOM) from headwater streams impacted by valley fill?

Evaluating these types of cumulative impacts becomes, almost by default, a modeling exercise of the production, downstream routing, and reutilization of organic matter or nutrients (e.g., LDOM model in a fifth order basin).

In addition, the cumulative impacts on flow paths and residence times of water should be considered more closely, particularly regarding how such impacts that may be indicated in headwater streams result in such impacts in downstream waters. The draft EPA report should assess whether MTM-VF effects flow and flow regimes downstream, and, if so, how in turn does this affect aquatic life.

4.5.2.4. Food Web: Do food web impacts downstream of one or more MTM-VF's develop in a cumulative fashion as an upward cascade from lower to higher trophic levels due to differences in exposure mechanisms (e.g., vulnerable physiology vs. bioaccumulation)? Do changes in downstream functional feeding groups reflect altered food inputs due to VF?

Selenium may occur at low, non-toxic, but persistent levels below MTM-VF's initially but, because of its nature (lipophilic), could gradually reach levels in the tissue of stream organisms that are toxic or debilitating. Similarly, some food inputs may be conspicuously reduced or missing below MTM-VF's (e.g., whole leaves, large woody debris) which, in turn, could simplify the food web and cause the extirpation of certain taxa (e.g., caddisfly genus Lype which feeds on woody debris) or functional feeding groups (e.g., shredders, miners). Tests on salamanders as well as brook trout would be recommended to assess such impacts.

Evaluating cumulative food web impacts may be evident in published data on community structure (loss of taxa in certain functional groups) or might be gleaned from tissue analyses archived or of freshly collected samples of taxa representing certain trophic levels along a gradient downstream from the MTM-VF sites in a watershed. Selenium might be a good candidate for this type of analysis.

4.5.2.5. Synergistic: Do the impacts associated with MTM-VF interact among stressors associated with mixed land use in the watershed (e.g., forest clearing, agriculture or urbanization) or with more regional stressors (acid rain, atmospheric deposition of nutrients, climate change)?

In terms of synergistic cumulative impacts associated with interactions among stressors, the relationship between MTM-VF stressors and those associated with other watershed alterations have apparently not been pursued. Studies on interacting stressors should be included in the EPA review. Some confounding stressors can be tested and evaluated with existing data. For example, it is known that the toxicity of many compounds is, in fact, dependent on temperature and the level of hardness of the water. Thus, the extent to which clear cutting and ponding of water associated with MTM-VF increases stream temperature and could or does exacerbate the toxicity of suspected key factors should be considered. In addition, some potentially toxic substances (e.g., Se) may reach toxic levels only after cross contamination with inputs from other land uses (e.g., application of pesticides especially fungicides for agriculture). A few studies that have reported an interaction between chemical stressors and regional factors include Brooks et al. (2007), Clements et al. (2008), Paine et al. (1998), and Schindler et al. (1990).

As an alternative to the above, the Panel also briefly considered the following approach to viewing cumulative impacts by dividing them as follows:

(i) **time** (i.e., slow vs. fast responses, and the associated continuum)

(ii) **space** (see above)

(iii) **activities** (see synergistic cumulative impacts above: target contaminant + x + y + z and so forth)

(iv) **biotic responses** (how many response variables need to change by how much before the system no longer functions normally?)

4.5.3. Specific Comments (Terrestrial Ecosystems)

For evaluating the cumulative impacts on terrestrial ecosystems eliminated by MTM-VF operations, the Panel proposes that equal consideration needs to be given to the negative impacts associated with forest fragmentation (loss of interior forest, loss of forest due to road construction) and degradation of interior forest at the periphery of MTM-VF sites, as well as potential positive cumulative impacts associated with the new, altered terrestrial ecosystems left behind. Certain types of alteration may be considered positive in some aspects and negative in other aspects (e.g., conversion to grassland is positive for some wildlife but negative for interior birds).

Cumulative negative impacts accrue both directly and indirectly. Direct impacts include the permanent loss of interior forest and replacement with a more simplified terrestrial ecosystem (usually grassland). This process fragments species associated with the remaining interior forest of the region and creates areas of unnatural local habitat colonized by species whose populations are highly fragmented due to the patchy nature of the new habitat. It is well known that the local abundance of almost every breeding species studied in the interior of upland forests is significantly influenced by factors such as reduced forest area, increased isolation, and loss of structure. Unlike streams, where locating MTM-VF's in nearby but different watersheds might help ameliorate downstream cumulative effects from a high density of sites, increased density of MTM-VF sites causes cumulative impacts to the overall forest and these impacts ignore watershed boundaries. Cumulative direct impacts due to forest removal associated with MTM-VF currently remain theoretical due to lack of published data but reasonable estimates of the degree and extent of impact might be gleaned from published literature on forest fragmentation associated with other land uses that involve deforestation (e.g., clearcut timber harvest). In some respects, however, the effects of these other conversions will likely differ markedly from MTM-VF. The draft EPA report should recognize and consider the relationship between the impacts due to MTM-VF and extent of impact from other land uses. For example, data from Ohio and other agriculturally drained streams in the Midwest has identified that cumulative loss of habitat has over the past 100 years caused the extirpation of sensitive species from watersheds and basins and lead to broadly degraded aquatic assemblages. It is difficult to detect the short-term gradual changes in aquatic assemblages in response to gradually increasing stressor loads that might accrue over time. Species can often persist for years or decades until a combination of natural events (e.g., drought) and anthropogenic stressors result in local extirpations. Indirect impacts result because factors associated with deforestation of the MTM-VF sites penetrate the residual forest surrounding each site and cause gradual and cumulative changes (mostly negative), especially to the understory and associated wildlife. Penetrating factors include, among other things, increased levels of light and temperature, decreased levels of moisture, and higher density of herbivorous mammals and parasitic birds. These indirect effects mean that the scale of the overall impact of deforestation due to MTM-VF's on interior forest habitat of a region is greater than the sum of the absolute total loss of forest associated with the specific MTM-VF's. Measurements of the cumulative indirect impact might include the gradual increase in certain penetrating factors. For example, an increase in species such as deer, elk or invasive plants in edge-of-woods habitat surrounding the MTM-VF's or an increase in invasive species preferring grassland habitat bordering woods such as cowbirds which negatively affect nearby forest-nesting bird species.

The Panel also felt that inclusion of birds and bats that rely on adult forms of aquatic insects and even mammals such as raccoon, opossum, and mink that are typically water-oriented also bear mention even if indirect effects are likely difficult to quantify. The report should further discuss the impact of loss of headwater streams on amphibian populations. Over 10% of the world's salamander diversity is found in this region and headwater streams are critical to their existence.

Another potentially important component could be interactions between pH and algal production. Significant pH swings related to photosynthetic activity resulting from increased light and nutrients could cause metals—already at higher concentrations in MTM-VF streams than reference streams—to come in and out of solution, potentially increasing toxicity.

As noted above, although forest fragmentation is generally viewed as one of the greatest threats to biodiversity in forests, one could view some of the cumulative impacts associated with permanent conversion of interior forest to grassland as being beneficial. For example, creating new habitat for species such as elk, deer, or native grassland species of birds could be viewed as a positive effect associated with forest fragmentation in a forested area where such habitat is rare. Moreover, patches of grassland habitat could have a beneficial effect by increasing the regional population size and facilitating gene flow for grassland species, although this must be balanced against the loss of regional biodiversity in a region where biodiversity is among the greatest in the world. However, it must be recognized that these same benefits come at a cost to interior forest species where forest fragmentation reduces population size and gene flow. Currently, it is not clear that there is sufficient data available to quantify the short and long-term (cumulative) benefits and costs associated with the type of ecological trading that has been and is being precipitated by MTM-VF. As noted above, studies of clear cut timber harvest may be worth mining as it could provide good insights into the potential impacts of this ecological trading.

Also, given the limited available data, perhaps the draft EPA report should include additional comparison of how MTM-VF effects may be similar or different from urban and agricultural impacts where cumulative effects have been documented.

In addition, EPA should assess whether potential bioaccumulative effects to the food web appear to be additive or multiplicative, or linear or non-linear.

4.6. Charge Question 6: The Surface Mining Control and Reclamation Act and its implementing regulations set requirements for ensuring the restoration of lands disturbed by mining through restoring topography, providing for post-mining land use, requiring re-vegetation, and ensuring compliance with the Clean Water Act. Does the review appropriately characterize the effectiveness of currently employed restoration methods?

4.6.1. General Comments

Understanding restoration effectiveness, shortcomings, and potential for improvement is essential for understanding how best to manage impacts from MTM-VF. The Panel agrees with EPA's contention that there is little published evidence that current restoration approaches are effective in recovering aquatic ecosystem functions that have been lost as a result of MTM-VF. However, there are several important issues that should be addressed further as described below. The review of restoration effectiveness would be improved by reorganizing this section under two major subheadings: "On-Site Reclamation" and "Off-Site Mitigation, citing certain available literature on the topic of restoration effectiveness, and identifying the most important shortcomings of current reclamation processes related to aquatic resources. The Panel encourages EPA to define restoration objectives, show how restoration can be used within the permitting process to ensure maintenance and improvement of watershed scale conditions, and discuss the relevance of state water quality standards and spatial and temporal boundaries associated with meeting restoration objectives. The panel also provides suggestions for research needs and additional references that should be considered.

4.6.2. Specific Comments

4.6.2.1. Objectives of Restoration: The effectiveness of currently employed restoration methods cannot be evaluated without a statement regarding the objectives of restoration. The Panel encourages EPA to address the following issues as they relate to restoration objectives:

- The term "restoration" must be explicitly defined. There is considerable debate in the literature regarding what is meant by the term restoration. For some, restoration implies full recovery of ecosystem structure and function to conditions that precede any human impact. This sets restoration apart from related terms such as reclamation, rehabilitation, enhancement, and mitigation. Recently, there has been emerging consensus that "restoration" encompasses all actions designed to recover all or part of ecosystem functions lost due to development activities. Following this trend, EPA should consider defining restoration in the current context as "all reclamation and mitigation actions designed to recover ecological functions lost as a result of MTM-VF mining."

  The charge question refers to all SMCRA requirements, including topography, land use, re-vegetation, and compliance with the Clean Water Act (CWA). Based on discussion with EPA at the July 20-22, 2010 meeting, it does not appear that the draft EPA report is seeking to address all of these requirements, but rather is focused on compliance with the CWA only. Assuming this, the Panel encourages EPA to use the report as an opportunity to address this question: "To what extent has it been shown that on-site reclamation and off-site mitigation (such as old mine retrofitting, stream channel restoration, riparian revegetation, acid mine drainage remediation, or municipal waste water treatment) are effective in restoring aquatic ecosystem function that is lost or degraded as a result of MTM-VF?"

ORD should discuss how a state's water quality standards are relevant to meeting restoration objectives within the draft EPA report. The definition of restoration should take into consideration how the restoration of surface mined areas relates back to the link with water quality standards. States designate their waters with regard to potential use which affects how their water quality standards would be set. The designated uses of the waters within state water quality standards would assist in clarifying restoration objectives and potential for success within a water body. The discussion should include a regulatory context regarding whether the CWA Section 404 permitting process allows the filling of valley areas and when or whether such filling constitutes the removal of an aquatic life use in the small headwater streams in the valley fills, and whether States have assigned aquatic life uses to these streams. The discussion should also include whether such fill would be considered an impairment to a use and whether such fill would affect the protection of downstream uses. EPA should also consider adding discussion on situations where states have only designated a single aquatic life use to reflect the wide range of potential aquatic life uses within its streams. This discussion should also consider related issues such as the difficulty in differentiating between ephemeral and intermittent streams and the inability to distinguish between high quality waters (either in the headwaters or further downstream), more "typical" waters, or more limited waters (i.e., those already affected by historical mining) with single aquatic life use designations, and the difficulty of customizing protection or restoration efforts in streams and watersheds with such aquatic life use designations.

- The final issue relating to restoration objectives has to do with spatial and temporal scale. Several questions arise related to these objectives that should be considered by EPA when considering how to assess restoration effectiveness. For example, does the draft EPA report seek to describe restoration effectiveness only at the localized stream segment scale or does it include larger watershed scales? Likewise does the draft EPA report seek to describe near-term and long-term effectiveness of restoration actions? Over what time frames should conductivity and aquatic life be measured to assess effectiveness of restoration objectives? Where should conductivity and aquatic life be measured (given that the inflows and outflows to the region may have completely changed before and after a MTM-VF operation)? If there is poor conductivity at first, does this last for the long term? How is conductivity quantified given natural variability over flow regimes? Regarding when to measure – should measurements occur during periods in the life cycle of the aquatic response variables? Is restoring "good" conductivity sufficient to ensure success in terms of protecting aquatic life?

How should habitat be quantified and defined, both before and after restoration occurs? These are important questions because restoration objectives must be set, and ultimately assessed, within a spatial and temporal scale context. The Panel encourages EPA to define restoration objectives within the spatial and temporal scales of interest. Also, EPA should consider developing a case study for the draft EPA report that highlights key considerations for EPA-decision-making, to help the reader more fully understand how restoration objectives should be identified and assessed.

- Helpful citations can be found in Appendix 1. Appendix 1 includes papers on the importance of setting objectives for restoration as well as papers on the effectiveness of restoration.

4.6.2.2. Reorganize Section: The review of restoration effectiveness would be improved by organizing this section around two major subheadings: "On-Site Reclamation" and "Off-Site Mitigation."

4.6.2.2.1. <u>On-Site Reclamation</u>

- The Panel encourages EPA to discuss current mine reclamation efforts within the historical context of SMCRA implementation. It is particularly important to consider the significant progress that has been made over the past 30+ years, especially as it relates to: slope stability, soil development, reforestation, revegetation, storm-water control, sediment reduction, and acid mine drainage prevention and minimization. The CWA emphasizes "progress" with regards to environmental protection and impact minimization. Therefore, in order to properly assess the current management of surface mining impacts, EPA must consider current shortcomings within the context of historical progress. Only then can the following question be answered: Are we making progress with regards to mine reclamation and mitigation?

  The reclamation methods that have become most extensively used are grounded in more than just the current SMCRA recommendations. In the Appalachian ecosystems addressed by this document, SMRCA was concerned with the impacts of surface mining on hydrology (both surface and groundwater quality and quantity), soil erosion and development, and aesthetics. The lack of success reforesting surface mines, coupled with stream sedimentation and decreased water quality, impacted the decisions for the early SCMRA reclamation. Some state laws were more effective than others at protecting the water and terrestrial environments. Reclamation initially applied a preference for herbaceous ground cover to limit erosion, decrease impacts on stream water quality and improve soil development processes. Under this phase of SMCRA, storm-water and surface water were controlled, AMD impacts were decreased with metal and pH improvement, sulfide oxidation was minimized, mine soils were improved, and slope stability issues, especially with regard to mountaintop mine-valley fills, were controlled. Recent advances in revegetation, reforestation and soil development on reclaimed mines have been dramatic (see Ashby, 1999a and 1999b; Burger et al., 2009;

Burger et al., 2005; Groninger et al., 2007; and Sweigard et al., 2007a). The *Proceedings of the American Society of Mining and Reclamation* is an invaluable resource for peer-reviewed articles on surface mine reclamation. An example paper from these Proceedings includes Chermak et al. (2004).

- Once it has been acknowledged that there have been dramatic improvements in mine reclamation, then it should be possible to reach objective conclusions regarding current reclamation shortcomings. It also should be possible to assess whether there is any published evidence that the current shortcomings can be addressed through improved reclamation procedures. The Panel encourages EPA, through a review of the published literature, to identify the most important shortcomings of current reclamation processes as it relates to aquatic resources. The Panel understands that there are very few (if any) studies that have addressed this question directly within the MTM-VF region. Despite the evidence that reclamation methods are improving, the current literature questions whether stream channel reconstruction can effectively restore natural stream functions. This is based on: (1) a general understanding about the difficulty of reconstructing stream channels that function naturally (see Palmer et al., 2005; and Palmer and Allan, 2006); (2) a basic understanding of stream ecology; and (3) published studies that have quantified downstream impacts (see Harrison et al., 2004; Lepori et al., 2005; Merovich and Petty, 2007; and Sudduth and Meyer, 2006).

- Several recent studies cited in Appendix 1 have called into question the value of stream channel reconstruction in restoring natural stream functions (see Palmer et al., 2005; and Palmer and Allan, 2006). As indicated in the literature, effective restoration is particularly difficult on surface mines because of the diverse geology and rock fragment which, without high quality control construction oversight, results in infiltration rates that tend to create reconstructed channels that are dry except following heavy rain events (see Geidel and Caruccio, 1982). However, restoration efforts have improved and stream channels have been reconstructed. Further discussion is provided below on this topic.

Stream ecologists have spent much of the past 30 years working to elucidate the mechanisms of stream ecosystem processes. From this research, it is known that critical headwater stream functions include: habitat for sensitive, stream dwelling invertebrates (mayflies especially) and amphibians (stream salamanders); source of dilute, freshwater; detritus based food webs; and delivery of carbon and nutrients downstream (see Meyer and Wallace, 2001). Although the effects of MTM-VF on all of these functions have not been thoroughly examined, the Panel believes that current reclamation approaches are not likely to be effective in recovering all of these functions.

Some of the data presented indicates that MTM-VF effects on downstream ecosystems show elevated TDS and in some cases Se as important stressors. However, the data upon which these effects are based compare mined and/or filled areas versus unmined areas with no comment regarding the potential differences in geology. Differences in background water quality based on the environment of the coal deposition have been long known (Caruccio et al., 1977). While this information suggests that current reclamation processes are not completely effective in controlling TDS levels and associated increases in conductivity, the EPA should clearly define or recognize the range of variation of stratigraphic sequences for which conductivity and Se may reach problematic levels.

In the draft EPA report's Section 7.1.2 "Reclamation Bonds" discussion, several statements suggest potential difficulties in developing successful restoration. This discussion includes statements on the release of bonds upon completion of revegetation activities, and statements noting that reclamation to forested land is preferred. These statements both require further evaluation and discussion within the draft EPA report regarding the long-term success of such options. In addition, the draft EPA report should also consider studies and research that emphasize typical restoration methods and benefits for planting grasses, often non-native, instead of forests. Also, more data (information) from some citations would improve the discussion.

Despite the lack of published research on improved reclamation procedures, researchers from West Virginia University (WVU) and University of Kentucky (UK) have generated recent data that may be relevant to this discussion.

Of all the research needs listed in this document the most critical may be to develop and demonstrate methods that: 1) reduce the generation of conductivity in valley fills, 2) re-establish a functional forest (e.g., hydrology, water quality, sediment, organic matter, temperature regime), 3) re-establish a headwater stream that has critical functional capabilities and 4) address active fill construction impacts through passive treatment systems that encompass enhanced sediment/treatment pond capabilities. EPA should first consider assessing the available information associated with these research needs. Such information should be based on the following conditions:

- Achievement of low conductivity from valley fills. The UK studies discussed below have shown acceptable conductivity levels have been achieved at two reclaimed valley fills that were constructed using conductivity-producing material identification and isolation techniques (values less than 250 μS/cm).

- The Forest Reclamation Approach (FRA) has been clearly shown to be capable of re-generating mixed hard wood species on lands reclaimed using this technique (over 2.2 million trees as of 2007). The hydrologic response is that of a forested watershed which has quick flow from riparian areas and delayed flow (base flow) from upland areas. Once the forested is progressively established the terrestrial-related functions become increasing evident. Functional capabilities can be accelerated by replanting more established trees and shrubs in the riparian zone of re-established ephemeral and intermittent streams.

- Streams established using natural channel design techniques that address compaction below the stream bed and inter-connectivity to the riparian zone and ecosystem connections to undisturbed ephemeral and/or intermittent streams in close proximity to the valley fill should be further considered.
- Design and operate sediment control – treatment ponds to enhance performance especially regarding flow regime, water quality (conductance and sulfate), organics (including nutrients), and sediment contributions to more closely mimic natural forested conditions. This includes integration of passive riparian zone treatment systems that receives controlled discharge from the pond.

- Aggressively monitor stream functions and water quality of established headwater streams and down-stream impacts below the sediment/treatment pond throughout the pre-development, construction and well-after the reclamation.

The WVU research, which is reported in a graduate student thesis (Gingerich, 2009) and in an unpublished manuscript (Gingerich et al., unpublished manuscript), focuses on quantifying the full suite of aquatic ecosystem functions that are and are not recovered using current reclamation procedures.

The major conclusions from the Gingerich studies include:

1. The headwater catchments are completely rearranged by the mining/reclamation process.
2. The predominant stressors to the reconstructed systems are elevated TDS and sulfates.
3. There is a consistent replacement of sensitive lotic taxa with tolerant lentic taxa (invertebrates and amphibians).
4. Many of the typical headwater "functions" are retained to some degree, including organic matter (OM) retention, OM decomposition, and production of dissolved and fine particulate organic matter.

A summary table of the results indicated in the Gingerich studies shows the ratio between what is observed in reference headwater streams vs. what is observed in perimeter channels. Values less than one indicate conditions where that particular function is lower in constructed channels relative to native channels. It is critical to note that the headwaters are completely transformed and many functions are highly altered, but not all functions are completely lost, and still others are "accentuated." The question is, are there ways to improve the reclamation process such that functional losses or extreme modifications (+ or -) are minimized?

Ecosystem Function Variable	Functional Ratio
% lotic amphibians	0.06
% EPT*	0.10
Conductivity (inverse)	0.21
EPT richness	0.25
RVHA*	0.52
OM* decomposition rate	0.57
WVSCI*	0.71
Invertebrate biomass	0.92
Invertebrate richness	1.14
% lentic amphibians	1.65
OM processing (ret X decomp)	1.86
Dissolved organic carbon	2.32
OM retention	3.24
Larval amphibian biomass	26.60

*EPT = Ephemeroptera, Plecoptera, Trichoptera
RVHA = Rapid Visual Habitat Assessment score
OM = Organic matter
WVSCI = WV Stream Condition Index

The UK research has focused on achievement of lowered conductivity from valley fills and from reconstructed on-site channels. Not only were acceptable conductivity levels achieved, but a valley fill was retrofitted with four ephemeral streams and one intermittent stream using natural channel design and construction techniques and water quality and EPT (measured for the up-gradient reaches) has been re-established.

The combined WVU/UK research underscores the need to develop and demonstrate conductivity reducing technologies for application on newly constructed mines and through retro-fitting of existing mines. Research indicates that improved reclamation approaches should focus on conductivity-producing material isolation, under-channel compaction, natural stream channel design, and improved construction of perimeter sediment control structures to maximize aquatic ecosystem function and sulfate reduction.

Section 7.4 of the draft EPA report (‘Evidence of Recovery’) discusses the need to gather evidence of return of “normal” hydrology to downstream channels, and relates to the potential success of recovery of water quality, aquatic biota and stream ecological function. Efforts to re-create channels, wetlands, and other habitat on-site have had limited success. The draft EPA report emphasizes downstream conditions and functions and provides limited discussion relating size of area removed and filled to size of area that is or may be restored or mitigated, and additional discussion on this topic is warranted.

- The Panel encourages EPA to address upland/terrestrial objectives of reclamation within the draft EPA report or make a stronger argument for why consideration of this topic is outside the scope of the draft EPA report.

  This is an important issue in its own right, especially as it relates to wildlife habitat (e.g., elk and other grassland dependent wildlife), reforestation and timber production, landowner preferences, and soil development and carbon sequestration. Public comments considered by the SAB Panel also support this statement. The Panel understands that it is a large topic that may add an unacceptable level of complexity to an already cumbersome document. Nevertheless, the topic is too important to simply pass by. At the very least, the draft EPA report needs to make clear the difference between upland reclamation for upland objectives and upland reclamation as a means for meeting aquatic objectives.

4.6.2.2.2. <u>Off-Site Mitigation</u>

- ORD decided to omit the topic of off-site mitigation in the original draft of the draft EPA report. The Panel believes that the topic is too important to avoid, and thus encourages EPA to add a section on off-site mitigation in a revised document. It is impossible to fully assess the effectiveness of restoration as currently practiced without considering off-site mitigation, because it is such an important part of the MTM-VF permitting process. Based on current literature, on-site reconstruction of stream channels on mined lands have not been able to fully recover lost ecosystem functions. Consequently, off-site mitigation has been as a means for filling the lost function gap. Determining whether or not this is happening and whether or not mitigation actions can be improved must be a central part of future permitting procedures.

- The Panel is not aware of published research on the effectiveness of stream restoration as a form of mitigation in the MTM-VF region. Consequently, the Panel encourages EPA to assess the potential effectiveness of mitigation with reference to the general stream restoration literature (several papers are listed in the attached bibliography). Most studies of the effectiveness of stream restoration suggest that there are few “functional” benefits from structural restoration, with a few notable exceptions. Of greatest concern, however, is that the Panel is not aware of any published studies indicating that structural restoration is capable of meeting water quality goals related to conductivity and elevated TDS. Consequently, it is very unlikely that current mitigation procedures are having any positive effect on reducing important potential MTM-VF stressors related to TDS and/or conductivity.

- As with on-site reclamation, it is critical for EPA to examine the potential for improved mitigation procedures moving forward. The Panel believes that the draft EPA report should recognize that there are opportunities to improve the mitigation process through three lines of action:

1. Retrofitting old mines using procedures to minimize conductivity, maximize sulfate reduction, and maximizing ecosystem function of perimeter sediment channels (see discussion above under "on-site reclamation").

2. Enabling municipal waste water treatment in the surrounding areas as a form of mitigation for mining impacts. Merriam (2009) and Merriam et al. (In Review) demonstrated that the effects of mining and untreated wastewater interact to produce highly impaired stream conditions in some areas of the central Appalachians. Consequently, it should be possible to achieve measureable benefits through improved waste water treatment. The Panel recommends that the draft EPA report assess and perhaps encourage the use of wastewater treatment as a form of mitigation for mining related impacts due to the potential for resultant significant improvements in aquatic resources at the whole watershed scale.

3. Allowing structural restoration as a form of mitigation, but only in cases where quantitative watershed assessment has identified degraded physical habitat as a dominant factor limiting the condition of aquatic resources in the region. If elevated ions resulting in higher conductivity and/or poor wastewater services are dominant stressors in a watershed, then it does not make sense to invest resources in stream channel restoration. However, in some areas of the Appalachians, it is possible that degraded structural habitat is the dominant stressor limiting ecological functions. In cases such as this, it should be possible to use structural enhancements as a form of mitigation and a means for increasing watershed condition.

4.6.2.3. Watershed Scale: On-site reclamation and off-site mitigation are part of a broader process designed to restore and protect aquatic functions at a watershed scale.

- Restoration is one component of a complex process needed to manage impacts associated with MTM-VF. In recognition of this, the Panel encourages EPA to: (1) discuss explicitly how restoration fits into the causative flow diagram (Figure 12 of the draft EPA report); and (2) show how restoration can be used within the permitting process to ensure maintenance and improvement of watershed scale conditions.

  Figure 12 already includes some reference to the role of reclamation in affecting the causative pathways linking MTM-VF to aquatic impacts (e.g., reduced sedimentation). The Panel encourages the addition of other ways that on-site reclamation and off-site mitigation could be used to minimize impacts and maximize watershed scale conditions in addition to adding it as a human activity.

  Lastly, restoration is a critical element of a holistic process of managing impacts from MTM-VF. Recent research indicates that a successful management program will include:

1. Identification and long-term protection of relatively large blocks of undisturbed headwater catchments to serve as a source of dilute freshwater and sensitive lotic taxa;
2. Setting mining intensity thresholds or development intensity thresholds for sensitive watersheds to ensure maintenance of downstream conditions;
3. Development and implementation of best management practices for surface mine reclamation that are designed to minimize conductivity, minimize sulfide oxidation, maximize sulfate reduction, and maximize ecosystem functions of reconstructed stream channels on reclaimed mines; and
4. Use of off-site mitigation as a way to target dominant limiting factors in a region and maximize recovery of aquatic ecosystem functions at a watershed scale.

4.6.2.4. Other Considerations:

Little attention was given to the issue of upland recovery relative to the habitats required for species that use both the upland and aquatic ecosystems (e.g., amphibians). EPA should discuss to what extent these upland habitats support pre-mining species of amphibians, and what are the anticipated and/or measured levels of post-mining species richness of amphibians in the aquatic environments or the ditches, groins, retention basins and downstream channel (see Gingerich, 2009).

The restoration conveyance and retention structures are designed for 100 year storms (as noted on page 66 of the draft EPA report). The draft EPA report does not discuss and EPA should consider discussing the potential effects of failures in these systems, including the potential that large storms could "blow out" the sediment retention structures. Further, EPA should consider discussing what is the potential effect of increased stormwater flow through the modified landscape with respect to ion concentrations, nutrients, and sediments.

Impacts from reclamation activities on temperature regime have been documented, with elevated temperatures during fall, winter and spring, and reduced temperature ranges during summer.

Reconstituted soils used in the restoration may contain fertilizers. EPA should consider discussing what is the effect of elevated nutrient levels in runoff on stream nutrient levels, and whether this could be the cause of the elevated nitrate levels downstream.

The review could benefit from incorporation of literature from the field of landscape ecology with respect to the re-establishment of patch structure and diversity in regards to the reclamation process and potential long-term impacts on stream and riparian networks.

In addition, the review could benefit from incorporation of literature on stream recovery timeframe if elevated conductivity is reduced over time through application of Best

Management Practices (BMPs). Either the draft EPA report should incorporate such literature or note that there is a gap in this information

Additional references that should be considered and are related to this Charge Question are included within Appendix 1.

Appendix 1: References

Additional references that should be considered to be added include the following:

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Appendix 2: EPA's CHARGE TO THE PANEL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

National Center for Environmental Assessment

Office of Research and Development

June 10, 2010

MEMORANDUM

SUBJECT: Review of (1) "The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields" and (2) "A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams"

FROM: Michael Slimak, Associate Director *signed*
National Center for Environmental Assessment
Office of Research and Development

TO: Vanessa Vu, Director
Science Advisory Board Staff Office

This memorandum provides background information and specific charge questions to the Science Advisory Board (SAB) in its review of two reports prepared by EPA's Office of Research and Development (ORD). These reports were developed by the National Center for Environmental Assessment (NCEA) upon the request of EPA's Office of Water and Regions 3, 4, and 5. These reports help provide scientific information to support a set of actions EPA is undertaking to clarify and strengthen environmental permitting requirements for Appalachian surface coal mining operations, in coordination with other federal and state regulatory agencies.

Background

The purpose of the report entitled "The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields," is to assess the state of the science on the ecological impacts of Mountaintop Mining and Valley Fill (MTM-VF) operations on streams in the Central Appalachian Coal Basin. This basin covers about 12 million acres in West Virginia, Kentucky, Virginia, and Tennessee. The draft EPA report reviews literature relevant to evaluating five potential consequences of MTM-VF operations: 1) impacts on headwater streams; 2) impacts on downstream water quality; 3) impacts on stream ecosystems; 4) the cumulative impacts of multiple mining operations; and 5) effectiveness of mining reclamation and mitigation. The impacts of MTM-VF operations on cultural and aesthetic resources were not included in the review. EPA used two primary sources of information for the evaluation: (1) the peer reviewed, published literature and (2) the federal Programmatic Environmental Impact Statement (PEIS) on Mountaintop Mining/Valley Fills in Appalachia and its associated appendices prepared in draft in 2003 and finalized in 2005.

The second report entitled, "A Field-based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams," uses field data to derive an aquatic life benchmark for conductivity. This benchmark value may be applied to waters in the Appalachian Region that are near neutral or mildly alkaline in their pH and where dissolved ions are dominated by salts of sulfate and bicarbonate. This benchmark is intended to protect the biological integrity of waters in the region. It is derived by a method modeled on EPA's standard methodology for deriving water quality criteria. In particular, the methodology was adapted for the use of field data. Field data were used because sufficient and appropriate laboratory data were not available and because high quality field data were available to relate conductivity to effects on biotic communities. This draft EPA report provides the scientific basis for a conductivity benchmark in a specific region rather than for the entire United States.

Both of these reports were commissioned by EPA's Office of Water (OW) and Regions 3, 4, and 5 in order to provide information that will assist OW and the Regions to further clarify and strengthen environmental permitting requirements for Appalachian surface coal mining projects, in coordination with federal and state regulatory agencies. Using the best available science and applying existing legal requirements, EPA issued comprehensive guidance on April 1, 2010 that sets clear benchmarks for preventing significant and irreversible damage to Appalachian watersheds at risk from mining activities.

Specific Charge in Reviewing the Mountaintop Mining – Valley Fill Effects Report

> <u>Charge Question 1</u>: The Mountaintop Mining Assessment uses a conceptual model (Figure 12 of the draft document) to formulate the problem consistent with EPA's Ecological Risk Assessment Guidelines. Does the conceptual diagram include the key direct and indirect ecological effects of MTM-VF? If not, please indicate the effects or pathways that are missing or need additional elucidation.

> <u>Charge Question 2</u>: This report relied solely on peer-reviewed, published literature and the 2005 Final Programmatic Environmental Impact Assessment on Mountaintop Mining/Valley Fills. Does this assessment report include the most relevant peer-reviewed, published literature on this topic? If not, please indicate which references are missing.

> <u>Charge Question 3</u>: Valley fills result in the direct loss of headwater streams. Has the review appropriately characterized the ecological effects of the loss of headwater streams?

> <u>Charge Question 4</u>: In addition to impacts on headwater streams, mining and valley fills affect downstream water quality and stream biota. Does the report effectively characterize

the causal linkages between MTM-VF downstream water quality and effects on stream biota?

Charge Question 5: The published literature is sparse regarding the cumulative ecological impacts of filling headwater streams with mining waste (spoil). Does the review accurately describe the state of knowledge on cumulative ecological impacts of MTM-VF? If not, how can it be improved?

Charge Question 6: The Surface Mining Control and Reclamation Act and its implementing regulations set requirements for ensuring the restoration of lands disturbed by mining through restoring topography, providing for post-mining land use, requiring re-vegetation, and ensuring compliance with the Clean Water Act. Does the review appropriately characterize the effectiveness of currently employed restoration methods?

Specific Charge in Reviewing the Conductivity Benchmark Report

Charge Question 1: The data sets used to derive a conductivity benchmark (described in Section 2 of this report) were developed primarily by two central Appalachian states (WV and KY). Please comment on the adequacy of these data and their use in developing a conductivity benchmark.

Charge Question 2: The derivation of a benchmark value for conductivity was adapted from EPA's methods for deriving water quality criteria. The water quality criteria methodology relies on a lab-based procedure, whereas this report uses a field-based approach. Has the report adapted the water quality criteria methodology to derive a water quality advisory for conductivity using field data in a way that is clear, transparent and reasonable?

Charge Question 3: Appendix A of the report describes the process used to establish a causal relationship between the extirpation of invertebrate genera and levels of conductivity. Has the report effectively made the case for a causal relationship between species extirpation and high levels of conductivity due to surface coal mining activities?

Charge Question 4: In using field data, other variables and factors have to be accounted for in determining causal relationships. Appendix B of the report describes the techniques for dealing with confounding factors. Does the report effectively consider other factors that may confound the relationship between conductivity and extirpation of invertebrates? If not, how can the analysis be improved?

Charge Question 5: Uncertainty values were analyzed using a boot-strapped statistical approach. Does the SAB agree with the approach used to evaluate uncertainty in the benchmark value? If not, how can the uncertainty analysis be improved?

<u>Charge Question 6</u>: The field-based method results in a benchmark value that the report authors believe is comparable to a chronic endpoint. Does the Panel agree that the benchmark derived using this method provides for a degree of protection comparable to the chronic endpoint of conventional ambient water quality criteria?

<u>Charge Question 7:</u> As described, the conductivity benchmark is derived using central Appalachian field data and has been validated within ecoregions 68, 69, and 70. Under what conditions does the SAB believe this method would be transferable to developing a conductivity benchmark for other regions of the United States whose streams have a different ionic signature?

<u>Charge Question 8</u>: The amount and quality of field data available from the states and the federal government have substantially increased throughout the years. In addition, the computing power available to analysts continues to increase. Given these enhancements in data availability and quality and computing power, does the Panel feel it feasible and advisable to apply this field-based method to other pollutants? What issues should be considered when applying the method to other pollutants?

Background Reading Materials

The following documents are accessible via the hyperlinks provided below. These documents provide important background information from scientific, regulatory, and policy perspectives on mountaintop mining and valley fills and are recommended reading for the SAB Panel members.

1. Final Programmatic Environmental Impact Statement on Mountaintop Mining/Valley Fills in Appalachia – 2005
   htttp://www.epa.gov/region3/mtntop/eis2005.htm)
2. April 1, 2010 Guidance Memorandum on Appalachian Surface Coal Mining
   http://www.epa.gov/owow/wetlands/guidance/pdf/appalachian_mtntop_mining_detailed.pdf.