This draft report contains Panel member edits and comments on the 3/25/14 draft SAB Review of the EPA document titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft)*

EPA-SAB-14-xxx

The Honorable Gina McCarthy
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: SAB Review of the Draft EPA Report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*

Dear Administrator McCarthy:

The EPA's Office of Research and Development (ORD) requested that the Science Advisory Board (SAB) review the draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft)* ("Report"). The Report is a review and synthesis of the peer-reviewed literature on the connectivity or isolation of streams and wetlands relative to large water bodies such as rivers, lakes, estuaries, and oceans. The Report was developed by ORD to inform an EPA and U.S. Army Corps of Engineers rulemaking to clarify the jurisdiction of the Clean Water Act.

In response to the EPA's request, the SAB convened an expert panel to review the Report. The Panel was asked to comment on: the clarity and technical accuracy of the Report; whether it includes the most relevant peer reviewed literature; whether the literature has been correctly summarized; and whether the findings and conclusions are supported by the available science. The enclosed report provides the consensus advice and recommendations of the Panel.

The Report is a thorough and technically accurate review of the literature on the connectivity of streams and wetlands to downstream waters. The SAB agrees with two out of three of the EPA's major conclusions. The SAB agrees that the scientific literature supports the conclusion that streams and bidirectional (riparian and floodplain) wetlands are physically, chemically, and/or biologically connected to downstream navigable waters. However, the SAB recommends some revisions to improve the clarity of the document, better reflect the scientific evidence, and make it more useful to decision-makers. The SAB disagrees with one of the Report's key conclusions concerning the connectivity of non-floodplain wetlands. In this latter case, the SAB supports a more definitive statement that the scientific literature does provide adequate information describing the numerous functions of unidirectional wetlands that benefit downstream water quality. Our major comments and recommendations are provided below.

Commented [AA1]: (Aldous) Additional text.

Commented [AA2]: (Aldous) Additional text.

Commented [LJ3]: (Johnson) Is an overarching recommendation that we'd like to see the information presented in a more quantitative manner. "The key conclusions in the Report should be more empirically and/or more specifically described. Wherever possible, the degree of and/or strength of evidence for connectivity should be quantified (e.g., of X studies, X% support conclusion of connectivity.

- The Report often treats connectivity as a binary property, either present or absent, rather than as a gradient. In order to make the Report more technically accurate ~~and useful to decision makers,~~ the SAB recommends that the interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude, and consequences of those connections.

- The Report presents a conceptual framework that describes the hydrologic elements of a watershed and the types of connections that link them. The literature review supporting the framework is technically accurate and clearly presented. However, to strengthen and improve its usefulness, the SAB recommends that the framework be expressed as spatially continuous physical, hydrological (surface and subsurface), chemical, and biological flowpaths that connect watersheds. The water body classification system used in the Report should be mapped onto the flowpath framework to show that continuous phenomena interact across landscape settings. In addition, the SAB recommends that each section of the Report be clearly linked to the framework.

- The SAB recommends that the Report more explicitly address the cumulative and aggregative effects of streams, groundwater systems, and wetlands on downstream waters. In particular, the Report should contain a discussion of the spatial and temporal scales at which streams, groundwater systems, and wetlands are functionally aggregated. We also recommend that, throughout the Report, the EPA expand coverage of several important issues including the role of biological connectivity, biogeochemical transformation processes, and the effects of human alteration of connectivity.

- In the Report, the EPA has classified waters and wetlands as either having the potential for "bidirectional" or "unidirectional" hydrologic flows with rivers and lakes. The SAB finds that these terms do not adequately describe the four-dimensional (longitudinal, lateral, vertical, and temporal) nature of connectivity and recommends that they be replaced with more commonly understood terms that are grounded in the peer-reviewed literature.

- The SAB commends the EPA for the comprehensive literature review in the Report. To make the review process more transparent, we recommend that the EPA more clearly describe the approach used to screen, compile, and synthesize the information. The EPA should verify and explicitly state that the Report summarizes those studies that failed to show connectivity along with those that demonstrate connectivity.

- The SAB finds that the review of the literature describing connectivity of headwater streams reflects the pertinent literature and is strongly grounded in current science. The literature review provides strong scientific support for the conclusion that ephemeral, intermittent, and perennial streams exert a strong influence on the character and functioning of downstream waters and that all tributary streams are connected to downstream waters. We recommend that the literature review more thoroughly address hydrologic exchange flows between main

Commented [JM4]: (Meyer) The recommendation of a gradient rather than dichotomous approach is part of the discussion of non-floodplain wetlands (e.g. Report p. 52); yet when this recommendation is made here, it sounds as though it refers to streams as well, and I do not think this is supported in what has been written in the report. In fact, on the next page (line 33) we state "all tributary streams are connected to downstream waters." That does not sound like a gradient of connectivity to me!

Commented [AA5]: (Aldous)

Commented [GA6]: (Ali) I would like the difference between "strength" and "magnitude" to be explained better, and I would also like the frequencyaspect to be included in this statement as it can be critical in assessing the importance/significance of connections.

Commented [MG7]: (Gooseff) Should we include frequency?

Commented [JH8]: (Harvey) Recommend preceding the word continuous with the word spatially so as to be clear that iit is continuity in space and not time

Commented [KK9]: (Kolm) Need to include physical for the geomorphological connectivity including topographic connectivity (valleys, channels) and physical sediments in the geomorphological environment (eolian and fluvial) and for the geological/hydrological/hydrogeomorpological connectivity including subsurface connectivity flow through porous media and fractured/karst materials).

Commented [AA10]: (Aldous) This needs clarification.

Commented [KK11]: (Kolm) The ultimate connector in many examples is groundwater and we need to emphasize it up front.

Commented [KF12]: (Fausch)

Commented [JH13]: (Harvey) Do we need to be concerned that this appears to contradict another recommendation we make that the report state that "over sufficiently long time scales all aquatic habitats are connected to downstream water?

Commented [JH14]: (Harvey)

Commented [KK15]: (Kolm) There is abundant literature regarding the physical, chemical, and biological connectivity of systems due to groundwater systems, and due to physical, chemical, and biological sediment in surface water systems that needs to be cited.

channels and off channel areas, the influence of stream temperature on downstream waters, and the movement of biota throughout stream systems to use critical habitats.

- The SAB finds that the literature synthesis on the connectivity of waters and wetlands in riparian/floodplain settings is ~~has been correctly~~ summarized correctly in the Report. There is strong scientific support for the overall conclusion that riparian and floodplain water bodies and wetlands are highly connected to receiving waters through multiple pathways. However, the SAB recommends that the Report be reorganized to clarify the functional role of floodplains and riparian areas in maintaining the ecological integrity of streams and rivers. Further, we~~We also~~ recommend that the Report more fully reflect the literature on lateral exchange between floodplains and rivers, and more explicitly discuss how floodplain environments are linked to river systems by means of the flood pulse.

- The SAB finds that the review and synthesis of the literature on the connectivity of non-floodplain ("unidirectional") waters and wetlands is generally thorough, technically accurate, and clearly presented. We recommend including additional information on material flows generated by fauna, particularly avian fauna.

- The SAB disagrees with the EPA's conclusion that the literature reviewed did not provide sufficient information to evaluate or generalize about the degree of connectivity (absolute or relative) or the downstream effects of wetlands in unidirectional landscape settings. The SAB finds that the scientific literature does provide information to support a more definitive statement and recommends that the EPA revise the conclusion to better articulate: 1) those aspects that are clearly supported by the literature and, 2) the issues that still need to be resolved.

- The SAB also recommends that the Report indicate that over sufficiently long time scales all aquatic habitats are connected to downstream waters through the transfer of water, chemicals or biota, though the magnitude and effects of these connections vary widely across wetlands.

- Finally, the SAB finds that the EPA's Report could be strengthened by careful editing to ensure that it is more clearly organized-, concise, and written in a consistent style and voice.

The SAB appreciates the opportunity to provide the EPA with advice on this important subject. We look forward to receiving the agency's response.

Sincerely,

Commented [SF16]: **(Fennessy)**

Commented [MS17]: **(Sullivan)** There was not general consenasus that the literature on connectivity of waters and wetlands in floodplain settings was properly summarized, but rather that the focus was largely on non-floodplain riparian zones.

Commented [KK18]: **(Kolm)** The linkage of floodplains and rivers is primarily through groundwater systems and needs to be stated. Flooding is just a recharge event for the groundwater systems, and affects the water tables significantly in the short term, but the long term connectivity between groundwater system and the river is significant for chemical and biological activity on both the surface and in the subsurface.

Commented [SF19]: **(Fennessy)**

Commented [SF20]: **(Fennessy)** Do we want to limit this comment to avian fauna, or include fauna more generally

Commented [LJ21]: **(Johnson)** This could be strengthened to state why this is so important (e.g., because literature has document significant contributions of…

Commented [JT22]: **(Tank)** This should be a separate bullet.

Commented [sf23]: **(Fennessy)**

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board (SAB), a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The SAB is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names of commercial products constitute a recommendation for use. Reports of the SAB are posted on the EPA Web site at http://www.epa.gov/sab

U.S. Environmental Protection Agency
Science Advisory Board
Panel for the Review of the EPA Water Body Connectivity Report

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Commented [M24]: (Murphy)

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Table of Contents

1. EXECUTIVE SUMMARY

The National Center for Environmental Assessment in the EPA Office of Research and Development (ORD) has developed a draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft).* The draft report (hereafter referred to as the "Report") is a review and synthesis of the peer-reviewed scientific literature on the connectivity or isolation of streams and wetlands relative to large water bodies such as rivers, lakes, estuaries, and oceans. The purpose of the Report is to summarize the current understanding of these connections, the factors that influence them, and the mechanisms by which connected waters affect the function or condition of downstream waters. The Report was developed to inform an EPA and U.S. Army Corps of Engineers rulemaking to clarify the jurisdiction of the Clean Water Act. The Report is a scientific review and, as such, it does not set forth legal standards for Clean Water Act jurisdiction.

The literature review and synthesis in the Report focuses on describing: (1) a conceptual framework that represents the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and the watershed climatic factors that influence connectivity at various spatial and temporal scales; (2) the downstream connectivity and effects of ephemeral, intermittent, and perennial streams; (3) the downstream connectivity and effects of waters and wetlands in riparian/floodplain settings; and (4) the downstream connectivity and effects of waters and wetlands in non-riparian/non-floodplain settings. ~~Four~~ Six case studies from the literature are included in the report to illustrate the connectivity of water bodies in different landscape settings and geographic regions.

The EPA asked the SAB to review the Report and comment on: the clarity and technical accuracy of the document; whether it includes the most relevant peer reviewed literature; whether the literature has been correctly summarized; and whether the findings and conclusions in the Report are supported by the available science. This Executive Summary highlights the findings and recommendations of the SAB in response to the charge questions provided in Appendix A.

Overall Clarity and Technical Accuracy of the Report

The SAB was asked to provide its overall impressions of the clarity and accuracy of the Report. The SAB generally finds that the Report is an extensive review of the literature on the connectivity of streams and wetlands to downstream waters that is both thorough and technically accurate. However, the Report could be strengthened by careful editing to ensure that it is more clearly organized, concise, and written in a consistent style and voice. Some terms and definitions are not used consistently in all parts of the document. The SAB recommends that a revised ~~the~~ conceptual framework proposed in these comments which describes~~describing~~ the hydrologic elements of a watershed and the connections that link them be used to integrate the entire Report. Each section of the document should be clearly linked to this framework. In addition, the key points in each chapter of the Report should be clearly stated at end of the chapter, and a succinct table summarizing all of the key findings of the Report should be included in the executive summary.

The Report is a science, not policy document, but it was written to support the EPA's efforts to clarify the jurisdiction of the Clean Water Act. The SAB finds that the report could be more useful to decision-makers if it brought more clarity to the interpretation of connectivity, especially with respect to: (1) quantification of the degree, magnitude, or consequences of connectivity, and (2) the cumulative or

Commented [M25]: (Murphy) I haven't edited the ES and Introduction **since** they might need a complete overhaul. This **said**, I found these two parts of the report very well written, reflective of the group concensus, and without much need of change. Id like to see the rest of the report brought up to the same level of clarity.

Commented [LJ26]: (Johnson) Have we sufficiently addressed the role of humans in changing / exacerbating natural disturbance regimes and the subsequent impact on connectivity? E.g., drought impacts on connectivity are exacerbated by water extraction; wetland drainage, channelization,

Commented [MJ27]: (Josselyn) See comments on the executive summary that are included in the Panel's general comments.

Commented [GA28]: (Ali)

Commented [D29]: (Patten) is this statement supported by all of the commentary and suggestions of the review? Is there another way of saying this that isn't so "absolute"?

Commented [SF30]: (Fennessy)

Commented [LJ31]: (Johnson) Including the glossary

Commented [AA32]: (Aldous)

Commented [GA33]: (Ali) The terms "degree", "strength", and "magnitude" mean pretty much the same thing. This statement says nothing about frequency and duration though.

Commented [JM34]: (Meyer) give an example of the terms we are recommending. It would make this much clearer

aggregate effects of streams and wetlands on downstream waters. The Report often treats connectivity as a binary property, either present or absent, rather than as a gradient. The SAB recommends that the interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude and effect of those connections. The SAB also recommends that the Report more explicitly address the cumulative effects of streams and wetlands on downstream waters, particularly the spatial and temporal scales at which streams and wetlands are functionally aggregated.

The literature review in the Report could be strengthened by more clearly describing the approach used to screen, compile, and synthesize the information and by including additional references provided by the SAB. The EPA should confirm and state that studies failing to show connectivity were cited in the Report along with those that demonstrate connectivity. The SAB finds that the case studies in the Report provide helpful illustrations of the connectivity of streams and wetlands in certain geographic areas to downstream waters, but the relevance of the case studies would be more apparent if the Report explained how they were selected and also presented them more succinctly in text boxes throughout the document.

Clarity and Technical Accuracy of the Conceptual Framework in the Report

The SAB was asked to comment on the clarity and technical accuracy of the conceptual framework of watershed structure and function presented in the Report. The literature review supporting the conceptual framework is thorough and technically accurate but the SAB recommends some revisions to improve the clarity, accuracy, and usefulness of the framework. Connectivity should be defined at the beginning of the Report and the SAB recommends that this definition include connections within and among entire watersheds and underlying aquifers. The EPA should clearly state in the Report what are considered "waters" and "wetlands" and how they are distinct from the federal regulatory definition.

The SAB recommends that the conceptual framework in the Report be expressed as continuous physical, hydrological (surface and subsurface), chemical, and biological flowpaths connecting watersheds. The framework should also illustrate the importance of climate, geology, and relief on flow and transport and highlight the four-dimensional (longitudinal, lateral, vertical, and temporal) nature of connectivity. In the Report, the EPA discusses connectivity within a classification system based on discrete landscape settings (i.e., rivers and streams; waters and wetlands in riparian/floodplain settings; and waters and wetlands in non-riparian/non-floodplain settings). The SAB recommends that this classification system be mapped onto the flowpath framework to show that continuous phenomena interact across these discrete landscape settings. There should be more emphasis in the conceptual framework on the importance of groundwater connectivity and biological connectivity. Additional layers of complexity also should be included in the conceptual framework to reflect important issues such as spatial and temporal scales and human alteration of the hydrological landscape.

In the conceptual framework, the EPA has classified waters and wetlands based on their potential to have bidirectional or unidirectional hydrologic flows with rivers and lakes. Some unidirectional wetlands are also called "geographically isolated wetlands." However, the terms "bidirectional" and "unidirectional" do not adequately describe the four-dimensional nature of connectivity and therefore should be replaced with more commonly understood terms that are grounded in the peer-reviewed literature. The term "geographically isolated wetlands" is misleading because all waters and wetlands are connected at sufficiently long time scales. The Report should explain that the term "geographically

Commented [GA35]: (Ali) The difference between strength and magnitude should be explained.

Commented [JM36]: (Meyer) Once again, the recommendation of a gradient approach recommended for wetlands is recommended for streams as well, and I do not think that is what we have recommended.

Commented [KK37]: (Kolm) Need to include physical for the geomorphological connectivity including topographic connectivity (valleys, channels) and physical sediments in the geomorphological environment (eolian and fluvial) and for the geological/hydrogeological/hydrogeomorpological connectivity including subsurface connectivity (flow through porous media and fractured/karst materials). See comments on the conceptual model section.

Commented [D38]: (Patten) should the temporal aspect of the four dimensions be added here and later? Basically explain this when first stated.

isolated" does not imply functional isolation. In addition, the SAB recommends that a summary and synthesis of the conceptual framework be added to the end of Chapter 3 of the Report.

Literature on Connectivity and Effects of Ephemeral, Intermittent, and Perennial Streams

The Report contains an excellent review of the scientific literature describing the connectivity of headwater streams to downstream waters. Nevertheless, further discussion of the literature on several specific topics is warranted. The review should be expanded to include more complete discussion of temporal dynamics of connectivity as well as the processes involved in hydrologic exchange flows between main channels and off channel areas. The discussion of naturally occurring chemical constituents, contaminants, contaminant transformation processes, and the influence of stream temperature on downstream connectivity also should be expanded. In addition, the Report should more thoroughly document the evidence that the biological integrity of headwater streams and downstream waters is affected by the movement of biota throughout the lotic system. Other important topics that should be further discussed include: the consequences of human alteration of headwater streams; aggregate and cumulative effects of headwater streams on downstream waters; the effects of streamside vegetation on stream ecosystems; the importance of reciprocal food-webs linkages between streams and their adjacent from riparian areas to stream ecosystems; the role of groundwater and sediments in determining connectivity, and the degree or strength of downstream connections.

Findings and Conclusions Concerning Ephemeral, Intermittent, and Perennial Streams

The Report concludes that streams exert a strong influence on the character and functioning of downstream waters and that all tributary streams are physically, chemically, and biologically connected to downstream waters. While strong scientific support has been provided for these conclusions and related findings, the conclusions and findings should be quantified whenever possible, related to the four dimensions of connectivity, (longitudinal, lateral, vertical, and temporal), and give more attention to biogeochemical transformations and biological connections. In addition, some hydrologic aspects of connectivity require additional detail. These include descriptions of key linkages and exchanges in tributary streams, such as groundwater-surface water interactions, as well as the role of transition areas between uplands and headwaters. Likewise, the Report should explain how hydrologic connectivity sustains both streams and aquifers, particularly in alluvial systems in the Southwestsouthwest and in karst systems in the eastern U.S. The EPA should also consider summarizing and displaying the conclusions in the Report in matrix form with brief characterizations of the temporal and spatial scales over which given functions or phenomena occur. Articulating the rationale for choosing the specific the case studies would help ensure that the keys points are well illustrated.

Literature on Waters and Wetlands in Riparian/Floodplain Settings

The literature synthesis on the connectivity and downstream effects of waters and wetlands in riparian/floodplain settings hasclearly supports been correctly summarized and characterized in the Report. The literature review substantiates thethe conclusion that floodplains, riparian areas, and waters and wetlands in riparian/floodplain settings support the physical, hydrological, chemical, and biological integrity of downstream waters. However, additional emphasis of certain topics, and in some cases review of more recent and diverse literature, is needed in the Report. The review of the literature on riparian and floodplain wetlands should be reorganized to clarify the functional role of floodplains and riparian areas in maintaining the ecological integrity of streams and rivers. The SAB recommends that

Commented [MR39]: (Rains) The Report already does this. We actually recommended that they go a step further, and not use this term at all to the extent possible.

Commented [MS40]: (Sullivan)

Commented [KK41]: (Kolm)

Commented [KK42]: (Kolm)

Commented [DP43]: (Patten)

Commented [D44]: (Patten) we say this and then add a "however" statement later on... is the literature truely "correctly summarized"??

Commented [MS45]: (Sullivan) There was general consensus among Panel members that the focus onnon-floodplain riparian areas was inappropriate for this section.

Commented [sf46]: (Fennessy)

Commented [SF47]: (Fennessy)

Commented [KK48]: (Kolm)

the Report discuss the functional role of floodplains and wetlands in the entire landscape setting. The term "bidirectional wetlands" should therefore be replaced with the term "waters and wetlands in riparian/floodplain settings" to reflect landscape position. The review should more fully reflect the literature on lateral exchange between floodplains and rivers followed by downstream transport. In addition, an integrated discussion of the functional attributes of floodplains as habitats should be included in the review.

Other topics should also be emphasized. The Report should more explicitly discuss how floodplain environments are intimately linked to river systems by means of the flood pulse. In this regard, the importance of the short duration high intensity and long duration low intensity events should be compared and contrasted. The Report should also review additional literature on: channel migration zones (which demonstrate the variable nature of connectivity of floodplains); the importance of sediment movement, erosion and deposition; lateral connections that create a diversity of habitats supporting a wide array of species; and human impacts on connectivity. In addition, the Report requires a more recent and diverse review of the biogeochemical implications of exchange flow, including the literature on the role of wetlands and floodplains as sources, sinks, and transformers of nutrients and other chemical contaminants. The SAB also recommends that the examples used in the Report be broadened to make it more representative of the U.S. In particular, studies on peatlands in floodplain settings and forested wetlands, including bottomland hardwoods, should be incorporated.

Findings and Conclusions Concerning Waters and Wetlands in Riparian/Floodplain Settings

The findings and conclusions concerning waters and wetlands in riparian/floodplain settings are discussed in Section 1.4.2 of the Report. There is strong scientific support for the overall conclusion that riparian and floodplain water bodies and wetlands are highly connected to downstream waters through physical, chemical, and biological pathways. However, additional literature would bolster the findings and conclusions in Section 1.4.2 of the Report. The SAB finds that many of the conclusions in the Report are drawn from literature related to riparian zones that are adjacent to water bodies other than floodplains that are periodically inundated (i.e., non-floodplain riparian zones) and that this weakens the potential opportunity to present direct evidence of connectivity (or lack thereof) between waters and wetlands in riparian/floodplain settings and receiving waters. A broad discussion of floodplain systems is warranted, including an explanation of the floodplain areas that can and cannot be classified as wetland.~~wetlands.~~ The discussion of the findings and conclusions should further address a number of other issues including: the temporal dimension of connectivity of waters and wetlands in riparian/floodplain settings; the role of these waters and wetlands in storing and transforming chemical constituents; the role of biological connectivity (including food webs), quantification of groundwater linkages, the effects of human alteration of connectivity; and the importance of considering aggregate/cumulative downstream effects of these waters and wetlands. In addition, the SAB recommends that the conclusions be more empirically and/or specifically described (e.g., indicating the percentage of studies that supported a conclusion) and that consistent terminology be used throughout the report to describe riparian and floodplain wetlands.

Literature on Waters and Wetlands with the Potential for Unidirectional Hydrologic Flows to Rivers and Lakes

In general, the EPA's review and synthesis of the literature on the downstream connectivity and effects of wetlands and open waters with the potential for unidirectional connectivity is thorough, technically

Commented [D49]: (Patten) *(September 2013 External Review Draft)(*here and elsewhere... by suggesting this change we are suggesting changing from hydrological flow description to a spatial landscape description whch is quite different in concept. We need to recognize that we are making that major shift in emphasis.

Commented [JT50]: (Tank) This is the first time in the summary that a specific Section location is mentioned (e.g., Section 1.4.2 of the Report). This should either be avoided for all subsections of the Executive Summary, or done for all. As it stands, it seems out of place to only mention this one.

Commented [MS51]: (Sullivan)

Commented [MS52]: (Sullivan)

Commented [KK53]: (Kolm)

Commented [JM54]: (Meyer) I find the requirement to state the % of studies supporting a conclusion to be unusual. One rarely sees that in a literature review.

Commented [JM55]: (Meyer) if we are critical of their use of the term "unidirectional," then when we use it, it should be in quotes

accurate, and clearly presented. The SAB recommends that the EPA consider adding some additional publications on biological connections and "geographically isolated" wetlands. Inclusion of publications that analyze material flows generated by birds is important as they spatially integrate these wetlands through their movements. The term "unidirectional wetlands" as used in the report is misleading because it implies one-way hydrologic flows when, in fact, connectivity can have many spatial and temporal dimensions. The SAB recommends that the terms "unidirectional" and "geographically isolated" waters and wetlands be replaced in the report with the term "non-riparian/non-floodplain waters and wetlands." The SAB also recommends that the EPA frame the discussion about the temporal and spatial scales, types, and gradients of various connections between and among floodplain wetlands and non-floodplain wetlands and downstream waters by considering the magnitude, duration and frequency of surface and subsurface connections. The magnitude, frequency, and ~~durations~~duration of the connections should be specified to the degree possible from the literature, with acknowledgment that all aquatic habitats are connected to downstream waters over sufficiently long time scales. In addition, the Report should discuss the importance of assessing wetland connectivity and connectivity pathways in terms of aggregated wetland complexes and the legacy effects of human disturbances.

Findings and Conclusions Concerning Waters and Wetlands with the Potential for "Unidirectional" Hydrologic Flows to Rivers and Lakes

The SAB disagrees with the EPA's overall conclusion in Section 1.4.3 of the Report indicating that "The literature we reviewed does not provide sufficient information to evaluate or generalize about the degree of connectivity (absolute or relative) or the downstream effects of wetlands in unidirectional landscape settings." To the contrary, the SAB finds that the scientific literature does provide information to support a more definitive statement (i.e., numerous functions of unidirectional wetlands have been shown to benefit downstream water quality) and recommends that the EPA revise the conclusion to focus on aspects that are clearly supported by the literature ~~and~~ as well as the issues that still need to be resolved. The SAB also recommends that the EPA's conclusions concerning "unidirectional" wetlands explicitly recognize connectivity as a gradient rather than a dichotomous categorical variable and highlight the fact that there are multiple mechanisms resulting in connectivity that occur over gradients of space and time. The following text should be included in these conclusions: *Over sufficiently long time scales all aquatic habitats are connected to downstream waters through the transfer of water, chemicals or biota, though the magnitude and effects of these connections vary widely among wetlands.*

The SAB recommends several revisions to improve the findings concerning "unidirectional" waters and wetlands. Reference to specific studies should be removed as the findings are intended to summarize general themes arising from a broad synthesis of the diverse literature. The key findings should be more explicitly presented and clearly explained in the text of the Report. In addition, the key findings should include: the biological functions and biological connectivity of unidirectional wetlands, differences between natural and manmade wetlands, the importance of spatial proximity as a determinant of connectivity, and the importance of cumulative or aggregate impacts of unidirectional wetlands.

Commented [MS56]: **(Sullivan)**

Commented [D57]: **(Patten)** see comment above... these two terms mix hydrological flows and spatial location... geographic isolated is not the only unidirectional (I don't think). There is some advantage to using "geographically isolated" separate from "undirectiohnal" as there are wetlands that are truly isolated with little if any outflows.

Commented [SF58]: **(Fennessy)** It seems we should be consisnt in our recommended terminology throughout this report

Commented [D59]: **(Patten)** can we support this statement? what do we mean by "sufficiently long time scales"? Millennia? This is an issue that may be raised wherever we use the concept "long time scale".

Commented [GA60]: **(Ali)** Throughout the report quotations should be used when referring to "unidirectional" and "bidirectional" wetlands, to reflect the fact that this is a terminology used in the EPA report but not a terminology or nomenclature that is adopted by the Panel.

Commented [DA61]: **(Allan)** It would be helpful if the SAB review could be more explicit on these numerous functions.

Commented [SF62]: **(Fennessy)**

Commented [D63]: **(Patten)** a wishy washy statement.... too all inclusive which brings us back to the concept of "sufficiently long time scale".... what does that mean or imply?

Commented [DA64]: **(Allan)** Is this really a good idea?

Commented [KK65]: **(Kolm)** Suggest adding that the SAB recommends that a systematic approach be taken to conceptualize the structure and function of "unidirectional/disconnected" wetlands. This should be undertaken by hydrogeologists, surface water, and groundwater hydrologists, who have the quantitative tools and conceptual models to determine the connectivity of both surface and subsurface hydrological systems to "unidirectional" wetlands and extend this to include biological connections.

2. INTRODUCTION

The National Center for Environmental Assessment in the EPA Office of Research and Development (ORD) has developed a draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft).* The draft report (hereafter referred to as the "Report") is a review and synthesis of the peer-reviewed scientific literature on the connectivity or isolation of streams and wetlands relative to large water bodies such as rivers, lakes, estuaries, and oceans. The purpose of the Report is to summarize the current understanding of these connections, the factors that influence them and the mechanisms by which connected waters affect the function or condition of downstream waters. The Report was developed to inform an EPA and U.S. Army Corps of Engineers rulemaking on waters that are under the jurisdiction of the Clean Water Act. The Report is a scientific review and, as such, it does not set forth legal standards for Clean Water Act jurisdiction.

The literature review and synthesis in the Report focus on describing: (1) a conceptual framework that represents the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and the watershed climatic factors that influence connectivity at various spatial and temporal scales; (2) the downstream connectivity and effects of ephemeral, intermittent, and perennial streams; (3) the downstream connectivity and effects of waters and wetlands in riparian/floodplain settings; and (4) the downstream connectivity and effects of waters and wetlands in non-riparian/non-floodplain settings. ~~Four~~Six case studies from the literature are included in the report to illustrate the connectivity of water bodies in different landscape settings and geographic regions.

The EPA asked the SAB to review the Report and comment on: the clarity and technical accuracy of the document, whether it includes the most relevant peer-reviewed literature, whether the literature has been correctly summarized, and whether the findings and conclusions in the Report are supported by the available science. In response to the EPA's request, the SAB convened an expert panel to conduct the review. The Panel held a public meeting on December 16-18, 2013 to deliberate on the charge questions. This report provides the findings and recommendations of the SAB in response to the charge questions in Appendix A. The SAB recommendations are highlighted at the end of each section of this report. The order in which the recommendations are presented does not connote their relative importance.

Commented [MJ66]: (Josselyn) My only comment on this brief introduction is that it should contain a statement on the number of written comments received from the public on the Draft Science Report, the number of comments received in public testimony, and how those comments were incorporated into the Panel review process.

3. RESPONSES TO EPA'S CHARGE QUESTIONS

3.1. Overall Clarity and Technical Accuracy of the Draft Report

Charge Question 1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, "Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence."

The SAB was asked to provide its overall impression of the clarity and technical accuracy of EPA's draft report on the connectivity of streams and wetlands to downstream waters. The Report is an extensive review of the literature that is generally ~~both~~ thorough and technically accurate. However, the SAB finds that the Report could be ~~strengthened~~ technically improved by careful editing to: (1) ensure consistency and continuity in style and organization throughout the document; (2) improve the usefulness of the document to decision-makers; (3) strengthen the literature review and conceptually clarify ecosystems according to the SAB's suggestions (e.g., water bodies in floodplains, geographically "isolated" water bodies); (4) provide additional detail and clarification of text and concepts in some parts of the document; and (5) restructure the case studies.

3.1.1 Style and Organization of the Draft Report

There are stylistic differences among the chapters of the EPA's Report, and the writing needs to be reworked for consistency and continuity so that it is written in a single voice. There also is a strong need to check for consistent use of terms and definitions among the chapters, subchapter sections, and the glossary. The authors also should exercise caution when using words that may denote particular legal or regulatory meanings (e.g., significant, adjacent). The Report is quite long and can be repetitive in places, and the main points are easily lost in the volume of material presented. Superfluous or redundant information should be removed, being careful that only concise text supporting the key findings is included. The EPA should consider hiring a technical editor to address these issues.

Several organizational changes will improve the readability of the Report. First, the conceptual framework should integrate the entire Report. Each section of the Report should be clearly linked to the conceptual framework. As written, the chapters of the Report are not always consistent with the conceptual framework. Second, each paragraph and/or subsection of the Report should have parallel structure where main points are clearly articulated at the end – perhaps even in bold or underlined text. Third, the key points should be stated simply and directly at the end of each chapter, not buried in detail. Fourth, the authors should consider including in the executive summary a succinct table that summarizes the key findings and levels of certainty of each finding within~~of~~ the Report. The report of the Intergovernmental Panel on Climate Change (IPCC 2007) is an excellent model.

Recommendations

- The Report should be edited to ensure that it is written in a consistent style and single voice.

- Terms and definitions should be used consistently throughout the Report and caution should be exercised when using words that may have legal or regulatory meanings.

Commented [M67]: (Murphy) This is the best written and organized part of the SAB report. Other sections need to follow this format/voice.

Commented [MM68]: (Murphy)

Commented [MS69]: (Sullivan)

Commented [D70]: (Patten) is it thorough? we suggest literature that will complement the literature reviewed and thus that review is not thorough... is there a wheezle word to use

Commented [MM71]: (Murphy)

Commented [D72]: (Patten) does statement does not support the statement that the review of literature was thorough.

Commented [JT73]: (Tank) "Strengthen the literature review" should be expanded to clarify that this should be in certain key, identified areas. After all, we have said numerous times that the literature review was extensive.

Commented [MS74]: (Sullivan)

Commented [KF75]: (Fausch) It might be useful to specify an example where the report is not consistent with the conceptual framework

Commented [LJ76]: (Johnson)

Commented [D77]: (Patten) recommendations repetitive of above paragraphs but maybe that is good to emphasize points... applies through this section...

- Superfluous or redundant information should be removed from the Report. Each section of the Report should be clearly linked to the conceptual framework.

- Each paragraph and/or subsection of the Report should have a parallel structure where main points are clearly articulated at the end.

- Key points should be clearly stated at the end of each chapter.

- A succinct table summarizing the key findings of the report should be included in the executive summary.

3.1.2. Improving the Usefulness of the Report to Decision-Makers

Although the Report is a science, not policy, document, the SAB is aware that it was written to support the EPA's efforts to clarify the jurisdiction of the Clean Water Act. As such, the Report could be written in a more strategic manner that focuses less heavily on reviewing the basic dynamics of systems and more on dealing with complex or nuanced issues about which the synthesis can provide important insights. For example, the degree, magnitude, or consequences of connectivity could be better quantified throughout the Report. The authors might consider an approach similar to that used in the report of the Intergovernmental Panel on Climate Change (IPCC 2007) which would provide an estimate of the relative certainty of connectivity or an effect. As written, the EPA Report often treats connectivity as a binary property – either present or absent, rather than as a gradient. The SAB is mindful of comments received from many members of the public who indicated that the binary perspective in the Report implies that any connectivity must significantly affect the biological, physical, or chemical integrity of downstream waters. As further discussed in Section 3.8.1 of this report, the SAB recommends that the interpretation of connectivity be revised from a dichtomous, categorical distinction (connected versus not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude, and consequences of those connections. The Report also would be strengthened if it were to more explicitly address the cumulative effects of streams and wetlands on downstream waters (i.e., streams and wetlands considered in "aggregate"), a form of connectivity. In particular, a discussion of the spatial and temporal scales at which streams and wetlands are functionally aggregated would be useful.

Recommendations

- There should be greater focus in the Report on complex issues about which synthesis can provide important insights (e.g., better quantification of the degree, magnitude or consequences of connectivity).

- There must be more analysis of the scientific literature to provide a better quantification of the degree, magnitude, and frequency of various hydrologic, chemical, and biological connections for each of the wetland types and "waters" that are discussed in the report to better understand the

Commented [LJ78]: (Johnson) And level of certainty.

Commented [MJ79]: (Josselyn) See comments on this section included in the general comments on the draft report.

Commented [LB80]: (Benda) It might be useful to stress the importance of describing and illustrating how strength of connectivity can be evaluated, measured or predicted for *each* of the main topics including streams and tributaries, floodplains/riparian areas, floodplain wetlands and non floodplain wetlands. The need for this is mentioned is several other areas in the SAB review but it could be highlighted here as well.

Commented [JT81]: (Tank) The use of the term "Report" (capitalized) throughout has referred to the document SAB reviewed, now the SAB Review document is mentioned as "this report" (no caps) in this line. The term then becomes confusing to a reader. Perhaps calling this document the "SAB Review" would distinguish it from "the Report".

Commented [GA82]: (Ali) I have concerns about the use of the terms degree, strength, and magnitude in the absence of the word frequency.

Commented [JM83]: (Meyer) The recommendation of considering a gradient of connectivity may be appropriate for wetlands, but I don't think it is appropriate for streams. I think we are diluting the extent and significance of stream connectivity by calling for it to be viewed as a gradient. We need to be clearer that this recommendation is directed at the discussion of wetlands, not streams. In making this recommendation we refer to a specific section of the report. This recommendation applies to that section; yet by putting it here without clarifying that it is specifically referring to non-floodplain wetlands, we are diluting the message that the literature says tributaries are connected to downstream waters. Figure 1 (on p. 48 of our report) is clear in that it refers to wetlands; we need that clarity here.

Commented [LB84]: (Benda)

Commented [LB85]: (Benda)

Commented [GA86]: (Ali) I have concerns about the use of the terms degree, strength, and magnitude in the absence of the word frequency.

Commented [JH87]: (Harvey) This may be difficult for EPA to do because there are few published studies that place results about the degree of connectivity in a broad comparative perspective.

consequences that they have on downstream water quality. Where there is uncertainty in the understanding of these consequences, such uncertainty needs to be discussed.

- As further discussed in Section 3.8.1 of this report, the SAB recommends that the interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude, and consequences of those connections.

- The Report should more explicitly address the cumulative and aggregate effects of streams and wetlands on downstream waters, a form of connectivity. In particular, the Report should contain a discussion of the spatial and temporal scales at which streams and wetlands are functionally aggregated.

- The Report should more explicitly explain how the scientific literature can be used to address the cumulative and aggregate effects of streams and wetlands on downstream waters. In particular the Report should determine if the scientific literature can support a more quantitative approach to the scale (both spatial and temporal) at which aggregation over a watershed (e.g. HUC classifications) should be considered to have an effect on downstream water quality.

- The Report must explain how the definitions in the Report for rivers, streams, and wetlands differ from those used in the Clean Water Act and its regulations and how such differences may affect the analysis contained in the Report. In addition, the Report should present an analysis of the differences in the functions associated with vegetated and non-vegetated wetlands as defined in the Report.

3.1.3. Strengthening the Literature Review

The literature review in the Report can be strengthened by clarifying what was considered as peer-reviewed literature, the kinds of evidence used to support the findings and conclusions in the Report, and the number and types of studies selected for review. The approach used for screening, compiling, and synthesizing information needs to be made explicit. In particular, the "weight of evidence" approach used to evaluate multiple references should be described in more detail. The SAB finds that the absence of references to studies that failed to show connectivity gives an appearance of bias towards certain studies or even perhaps an effort to "prove" that systems are connected. The literature review should include studies both showing and failing to show connectivity. If an exhaustive literature review of these studies has been performed, this should be explicitly stated in the Report. The SAB has provided numerous additional references in this SAB report and other references have been suggested in written comments from the public.

Recommendations

Commented [MJ88]: (Josselyn) Suggested rewording of previous recommendation.

Commented [GA89]: (Ali) I have concerns about the use of the terms degree, strength, and magnitude in the absence of the word frequency.

Commented [JM90]: (Meyer) The recommendation of considering a gradient of connectivity may be appropriate for wetlands, but I don't think it is appropriate for streams. I think we are diluting the extent and significance of stream connectivity by calling for it to be viewed as a gradient. We need to be clearer that this recommendation is directed at the discussion of wetlands, not streams.

Commented [JH91]: (Harvey) This may be difficult for EPA to do because there are few published studies that place results about the degree of connectivity in a broad comparative perspective.

Commented [LB92]: (Benda)

Commented [DA93]: (Allan) A good recommendation but perhaps could be clarified with some supporting language.

Commented [MJ94]: (Josselyn) Suggested recommendation on spatial and temporal scales

Commented [MJ95]: (Josselyn) Suggested new recommendation

Commented [MJ96]: (Josselyn) See recommendation for this section in the general comments on the draft report.

Commented [D97]: (Patten) how does this statement tie back to our saying that the literature was "thorough"?

Commented [JM98]: (Meyer) What stream studies have failed to show connectivity? I question whether there are any. If this comment is in reference to wetland studies, then that needs to be made clear. As currently written, the statement is too broad. We are implying that EPA has not cited studies that fail to show connectivity, and I do not think that is the case. We need to revise this wording to make it clear that we are not implying that EPA excluded studies that did not show connectivity; their review of the stream literature (which is the literature I know the best) certainly did not have this bias

- The literature review in the Report should be clarified to indicate: (1) what was considered to be peer reviewed literature; (2) the kinds of evidence used to support the findings and conclusions; and (3) the number and types of studies selected for review.

- The Report should clearly describe the approach used to screen, compile, and synthesize information.

- Studies that failed to show connectivity should be cited in the Report along with those that demonstrate connectivity.

- EPA should consider including in the Report additional information from references provided by the SAB and members of the public.

- The Report should analyze the scientific literature evaluated for this report to determine where it may be insufficient to draw conclusions on the degree of connectivity for certain wetland systems or geographic areas by preparing a table that shows the distribution of the scientific literature for various regions of the US.

3.1.4. Additional Detail and Clarification of Text Needed in the Report

As further discussed in other sections of this SAB report, the following topics in the EPA Report require clarification and/or additional detailed information:

- The importance and relevance of different spatial and temporal scales.
- Biological connections, especially for birds, mammals, and salamanders, across the full life cycle. As part of this, connectivity via food webs should be included.
- Case studies of a greater range of geographic regions (e.g., arctic) and systems, including human modified systems, forested wetlands, and bottomland forests.
- Why a watershed and groundwater basin perspective is needed to understand connectivity.
- The importance of considering water bodies in aggregate (e.g., populations of tributaries and populations of floodplains, floodplain wetlands and non-floodplain wetlands) for evaluations of connectivity.
- Human modifications and their impacts on connectivity. Modifications can include directly removing/diminishing or restoring/enhancing connectivity, roads, agricultural tiles, dams, pumping groundwater, irrigation, channelization, and other manmade infrastructure (piped streams, stormwater pipes). Differences in the functions associated with these man-altered systems and their natural counterparts should be evaluated using the scientific literature base.
- Definitions of river, unidirectional and bidirectional wetlands, geographically isolated wetlands, and consistent use of these terms in text; although see SAB recommendations that follow that advise replacing the terms of unidirectional and bidirectional wetlands and geographically isolated wetlands with other terms.

Commented [JM99]: (Meyer) What stream studies have failed to show connectivity? I question whether there are any. If this comment is in reference to wetland studies, then that needs to be made clear. As currently written, the statement is too broad. We are implying that EPA has not cited studies that fail to show connectivity, and I do not think that is the case. We need to revise this wording to make it clear that we are not implying that EPA excluded studies that did not show connectivity; their review of the stream literature (which is the literature I know the best) certainly did not have this bias

Commented [MJ100]: (Joselyn) Suggested additional recommendation

Commented [MJ101]: (Josselyn) See recommendation for this section included in the general comments on the draft report.

Commented [SF102]: (Fennessy) The report does deal with this to some extent. It might be helpful to give an example here to show more specifically what we are looking for, e.g., local- to landscape-scale physical, chemical, and biological exchanges…. Etc.

Commented [LB103]: (Benda) The need of including explicit discussion on spatial and temporal scales is mentioned throughout the SAB review document covering all main EPA connectivity topics, and it should be emphasized here (line 36), as well as elsewhere in the SAB review document, that spatial and temporal scales are central to evaluating, measuring and predicting the strength of connectivity and thus the significance of effects, and …

Commented [LJ104]: (Johnson) Do we want to have them focus on "material transfer"

Commented [MR105]: (Rains) Also population/metapopulation dynamics, which is brought up in at least two separate comments in the full review.

Commented [SF106]: (Fennessy) In addition, the existing case studies can be edited to make them more focused and succinct

Commented [MS107]: (Sullivan) Are we saying that we want more case studies?

Commented [KK108]:

Commented [LB109]: (Benda)

Commented [MJ110]: (Josselyn)

Commented [MG111]: (Gooseff) See my general comments. I am concerned that the definitions of stream and river that include both surface water and groundwat…

Commented [KF112]: (Fausch) Given that the SAB proposed not using the terms unidirectional and bidirectional, these seem out of place here.

Commented [GA113]: (Ali) It might be at odds to suggest better definition of these terms and then suggest that they be discarded later in this report.

Commented [MS114]: (Sullivan) We have recommended alternative terms for some of the terms used here. If we are recommending that other terms be used, i…

Commented [LB115]: (Benda)

Commented [JM116]: (Meyer) I thought we were saying that they should eliminate terms like geographically isolated and uni- and bi-directional wetlands. It seems …

- Future research, technological, and methodological needs that will improve our ability to understand and estimate connectivity.
- Groundwater connections (especially regarding floodplain and wetland connectivity) to other wetlands and surface water features.
- The role of chemical and biological substances/tracers in surface water and groundwater for establishing connectivity of water bodies.
- The role of sediment in surface water for establishing connectivity of water bodies.

Recommendation

- The topics listed above should be clarified or discussed in more detail in the Report.

3.1.5. Restructuring the Case Studies in the Report

The SAB finds that the case studies in the Report provide helpful illustrations of connectivity between downstream waters and geographically-specific types of systems. That said, case studies could be even more helpful if they were selected and organized to allow comparisons among geographic regions, such as Southwest arid and Midwest mesic systems. As discussed in Section ~~3.4.1~~3.2.5 of this report, comparisons among geographic regions could be accomplished by using ~~hydrology~~ climate, geology, and relief, (~~which varies~~ vary regionally~~)~~ and which form the basis of the concept of Hydrologic-Landscape Regions (i.e., HLRs) as a framework for the case studies. The case studies are currently long and densely-written accounts, and this can make it difficult to identify which concept is being illustrated. The rationale for selecting different case studies and the key points being illustrated by each should be explicitly stated early in the text. Each case study should have a conceptual model diagram showing the surface and subsurface flowpaths illustrating the connectivity between/among systems. An alternative structure that the authors might consider is to present the case studies as brief, easily read, textboxes that clearly and simply articulate key points. Within these textboxes the expanded versions could be referenced and included in appendices. As further discussed in Sections 3.3.10 and 3.5.6 of this report, it would be useful to include case studies of a human-dominated system and a ~~bottom land~~bottomland hardwood system in the Report.

Recommendations

- The case studies in the Report should be carefully selected and organized to allow comparison of the connectivity of water bodies in different geographic regions.

- The rationale for selecting different case studies and the key points illustrated in each should be clearly stated early in the text.

- EPA should consider presenting the case studies in text boxes throughout the Report. The text boxes could reference more detailed information in Report appendices.

3.2. Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

Commented [LB117]: (Benda) It might be good for the SAB and the EPA to indicate (suggest) what some of these "needs" are.

Commented [KK118]: (Kolm)

Commented [MJ119]: (Josselyn) I concur with these recommendations and that they should be removed from the body of the report and used only for the purpose of examples. This can best be achieved in a "text box" type of approach.

Commented [JM120]: (Meyer) This would be a good place to include the request for more reference to arctic systems.

Commented [MR121]: (Rains)

Commented [KK122]: (Kolm)

Commented [D123]: (Patten) why are these mentioned in particular when others might also be useful?

Commented [M124]: (Murphy) See general comments. Need to provide a conceptual model.

Charge Question 2. Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this Chapter and its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

The SAB was asked to comment on the clarity and technical accuracy of the conceptual framework of watershed structure and function presented in Chapter 3 of the EPA's Report and the usefulness of the framework in providing context for interpreting information in the Report. The SAB finds that the literature review in Chapter 3 of the Report is thorough, technically accurate, and readable. The literature review generally does not need to be changed, although it could be strengthened with technical editing. However, ~~the~~a conceptual ~~framework~~model for ecological connectivity needs to be ~~revised and~~ clearly articulated at the beginning of the Chapter ~~to better enable the reader to access and understand the material~~. As further discussed below, the SAB finds that the following revisions are needed to improve the clarity, accuracy, and usefulness of the conceptual framework in the Report: (1) connectivity should be clearly defined at the beginning of Chapter 3; (2) the scope of the Report (i.e., the breadth of the literature review) should be clearly defined at the beginning of Chapter 3; (3) the conceptual framework should be expressed as ~~continuous~~ physical, hydrological, chemical, and biological flowpaths; (4) certain terms (e.g., unidirectional and bidirectional) used in the Report should be replaced with more commonly understood terminology that is grounded in the peer-reviewed literature; (5) additional layers of complexity, such as the influence of human activities, should be represented in the conceptual model in the Report; and (6) a summary and synthesis of the conceptual model should be added at the end of Chapter 3.

3.2.1. Defining Connectivity

Because connectivity can be defined in many ways, the Report needs to define and concisely discuss what is meant by "connectivity" at the beginning of Chapter 3. Currently, connectivity is not defined until page 3-28, long after much of the conceptual framework, as currently described, has been presented and discussed. The definition of connectivity also should be extended to the entire landscape (i.e., not just to waters and wetlands but to entire watersheds and underlying aquifers) through a broader vision of local- to landscape-scale physical, chemical, and biological exchanges. The definition and discussion of connectivity at the beginning of Chapter 3 could be brief, with the many details and nuances to be addressed later in the following sections of the Chapter.

Recommendations

- Connectivity should be defined and discussed at the beginning of Chapter 3 of the Report, and a discussion included on how the scientific literature was used to establish the degree to which such connectivity was determined to have an effect on downstream water quality.

- The definition of connectivity in the Report should be extended to the entire landscape through a broad vision of local- to landscape-scale physical, chemical, and biological exchanges.

3.2.2. Defining the Scope of the Report

Commented [JM125]: (Meyer) Don't need this first sentence, which is just a restatement of the charge question written in the lines above it.

Commented [D126]: (Patten) this implies that no new important citations are or will be suggested. Is that so?

Commented [MM127]: (Murphy)

Commented [LB128]: (Benda) Here and in numerous other places in the SAB review document, the need for an improved conceptual framework expressed as continuous (4 dimensional) hydrological, chemical, and biological flowpaths is mentioned. It would be helpful to EPA if the SAB could provide additional guidance (illustrative) on what that conceptual framework might look like. In addition, here and in numerous other places in the SAB review document, the term "hydrological us used. I think that if "hydrological" is to be understood to be all encompassing, then here and at a few other strategic locations in the SAB review document, this should be clarified.

Commented [M129]: (Murphy) We have stated that discontinuity needs to be addressed, too.

Commented [KK130]: (Kolm)

Commented [JM131]: (Meyer) provide an example of the "commonly used terminology" that we are requesting them to use.

Commented [JM132]: (Meyer) I read this paragraph as a summary of our recommendations. If that is the case, then (5) needs to be more complete. It should be replaced with "5) additional layers of complexity (including a functional framework, spatial and temporal scales, the influence of human activities, the use of Hydrologic Landscape Regions, aggregate and cumulative effects, and map resolution) should be represented in the conceptual model in the Report." Otherwise, without that explicit list, it makes it sound as though we don't care about those recommendations.

Commented [MJ133]: (Josselyn) See my recommendation included in the general comments on the draft report.

Commented [MJ134]: (Josselyn)

Commented [MJ135]: (Josselyn) See my recommendation on this section in the general comments on the draft report.

The SAB finds that the scope of the Report, with respect to the types of wetlands and water bodies covered, needs to be clearly defined and discussed at the beginning of Chapter 3. As a synthesis of the scientific literature, the Report appropriately includes discussion of the relevant literature on hydrologic, climatic, and other processes that occur across landscapes to connect various water bodies and wetlands. The breadth of the literature discussed in the Report need not be constrained by regulatory definitions of waters and wetlands. ~~However~~; however, the SAB notes that a primary use of the Report is to assess connectivity among waters and wetlands and downgradient waters. As currently written, the Report is not clear about the degree to which its definitions of water bodies and wetlands include broader portions of the landscape (e.g., whether wetlands or rivers include their floodplains). The Report uses the wetland definition of Cowardin et al. (1979) to describe wetlands, and many public commenters have expressed concern about the potential expansion of the scope of jurisdiction of the underlying Clean Water Act – from "three-parameter[1]" to "one-parameter" waters and wetlands. These confusions and concerns could be explicitly addressed in a separate section outlining the scope of the Report immediately after the section defining connectivity. Waters and wetlands should be clearly identified as being the large set of waters and wetlands as defined by Cowardin et al. (1979), a subset of which is covered by the Clean Water Act as set forth under 33 CFR 328.3. As part of that discussion, the Report should explain why the Cowardin et al. definition of a wetland was used[2]. The SAB recognizes that the Report is a scientific and not a policy document, but finds that ignoring this distinction only serves to create unnecessary confusion and concern among the readership.

Recommendations

- The scope of the Report should be clearly delineated, with special attention paid to clearly defining what are considered waters and wetlands.

- The Report should consider the functional role of floodplains and riparian areas irrespective of their classification as wetlands or other water bodies (see discussion in Section 3.5.2 of this report). The Report should clearly indicate that waters and wetlands covered in the Report are considered to be the large set of waters and wetlands as defined by Cowardin et al. (1979), a subset of which is covered by the Clean Water Act as set forth under 33 CFR 328.3. As part of that discussion, the Report should explain why the Cowardin et al. (1979) definition of a wetland was used.

- The differences between the wetland and waters definitions used in the Clean Water Act regulations and those used in the Report should be clearly explained. The Report should document, based on the scientific literature, what differences this may have on determining the degree of connectivity between wetlands and waters with downstream water quality.

3.2.3. Use of a Flowpath Framework

[1] The "one parameter" wetland classification system (Cowardin et al., 1979) classifies an area as a wetland if it has one or more of the following three attributes: (1) the area supports predominantly hydrophytes at least periodically; (2) the land has substrate that is predominantly undrained hydric soil; or (3) the land has nonsoil substrate that is saturated with water or covered by shallow water at some time during the growing season of each year. The "three parameter" classification system (33CFR 328.3(b); USACE 1987) requires that an area have all three of these attributes to be classified as a wetland.

[2] In response to questions from the SAB about the use of the "one parameter" wetland classification, EPA scientists explained that much of the scientific literature does not specify the method used to delineate the wetlands under study. Thus, EPA scientists used the broader 'one parameter" definition of wetlands to more fully assess the entirety of the available scientific literature.

Commented [AA136]: (Aldous)

Commented [M137]: (Murphy) I am still not comfortable about using Cowardin et al 1979. The report is attempting to define what water bodies, wetlands or otherwise are included in the WUSA definition. Cowardin was developed to address other regulatory needs. The EPA report needs to develop its own definition.

Commented [SF138]: (Fennessy) An excellent account of our discussion

Commented [MS139]: (Sullivan) And other water bodies?

Commented [MJ140]: (Josselyn) new recommendation.

Commented [M141]: (Murphy) This is a crucial section. The writing needs to be simplified and made more concise. Further, the SAB report needs to write this to provide clear concepts and resultant terminology that consistently inform the entire rest of the discussion.

Commented [MJ142]: (Josselyn) See my comments on this section in the general comments on the draft report.

As currently written, Chapter 3 of the Report contains detailed information about river system characteristics, the effects of streams and wetlands on downstream waters, and factors influencing connectivity. However, the Chapter lacks an explicit conceptual framework, which makes it difficult to categorize and organize this detailed information. Thus, the SAB recommends that a conceptual framework be established and discussed at the beginning of Chapter 3. This conceptual framework could be expressed as continuous physical, hydrological (surface and subsurface), chemical, and biological flowpaths connecting watersheds from "ridge to reef," and therefore connecting waters and wetlands to downgradient waters. The flowpath framework should highlight the four-dimensional nature of connectivity, because four-dimensional connectivity scaled in a habitat to catchment context is a foundational aspect of freshwater ecology (e.g., Ward 1989). The flux and transformation of water, materials, and organisms – which fundamentally control the integrity of downgradient freshwater ecosystems – occur at varying rates primarily determined by climate, geology, and relief and areprimarily expressed in terms of surface-water and groundwater storage and flow through the landscape (e.g., uplands, wetlands, lakes, rivers, and floodplains). Therefore, these flowpaths are inherently multi-directional (i.e., longitudinal, lateral, vertical, and through time).

The flowpath framework could be briefly presented and discussed in the context of a revised Figure 1-1 (currently on page 1-2 of the Report), which could be moved to the beginning of Chapter 3 and expanded to include at least some representation of physical, hydrological, chemical, and biological flowpaths. In the revised figure, each representative type of flowpath could be color coded (e.g., physical= brown, hydrological=blue, chemical=red, and biological=green). The revised Figure 1-1would thus become Figure 3-1. In the conceptual framework, hydrological flowpaths should be expressed in terms of both surface-water and groundwater flowpaths, with the latter including the potential for groundwater connections to cross watershed boundaries. (e.g., . For example, the Ogallala aquifer) underlies parts of South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and the Floridan aquifer, underlies all of Florida as well as portions of Mississippi, Alabama, Georgia, and South Carolina. Chemical flowpaths should be expressed as largely following hydrological flowpaths, with subtle differences such as the typically tight nutrient spiraling that transitions to increasingly open spiraling from the headwaters to the outlet. However, chemical flowpaths could also be expressed as sometimes following biological flowpaths, with examples including marine-derived nutrients being transported to headwater streams by anadromous fish and nutrients being transported between waters and wetlands by birds that eat in one location and defecate in another. Biological flowpaths should be expressed as aquatic, terrestrial, and aerial flowpaths connecting watersheds internally, "ridge to reef," and "reef to ridge," and including the potential for biological connections to cross watershed boundaries. Taken to the extreme, the revised Figure 1-1 could become almost infinitely complex and equally incomprehensible, so it is important to clearly state that this is a conceptual framework with representative rather than complete flowpaths.

Groundwater connectivity, in particular, could be better represented in the Report. The U.S. Geological Survey (USGS) has published numerous reports and learning tools on groundwater connectivity, including examples of flowpath frameworks expressed in block diagrams (Heath 1983; 1984; Winter et al. 1998), including flows through floodplains. Care should be taken not to imply that bedrock is impermeable, given that groundwater flows through bedrock are important flowpaths that connect hydrologic landscapes over long distances and often across watershed boundaries (e.g., Roses et al. 1996).

Commented [D143]: (Patten) This may be the most critical recommendation of our report. This framework either demonstrates the connectivity that is important or side steps the often critical but ignored connections.

Commented [KK144]: (Kolm)

Commented [LB145]: (Benda) See previous comment about the use of the term "hydrological."

Commented [SF146]: (Fennessy)

Commented [D147]: (Patten) this statement or the parenthetical part of it should follow the statement earlier about "highlighting four dimensional nature...."

Commented [JT148]: (Tank) The description of the revision of Figure 1-1 (to be new Figure 3-1?) is somewhat long and a bit confusing. Perhaps it would be more effective if an example of new figure was inserted here?

Commented [KK149]: (Kolm)

Commented [KK150]: (Kolm)

Commented [D151]: (Patten) include in examples deep carbonate aquifer cross basin connections such as found in the Great Basin

Commented [DA152]: (Allan) Is reference to the Ogallala aquifer relevant? I thought this was a deep aquifer with relatively little connection to surface water and shallow ground water. If that is so, we are extending our time horizon to very long geological time.

Commented [AA153]: (Aldous)

Commented [AA154]: (Aldous) This section needs specific citations

Commented [SF155]: (Fennessy)

Commented [D156]: (Patten) see above comment. This is important because impacting GW in one basin can effect flows in another including flows of rivers.

An important next step is to state how the revised conceptual framework is used in the Report. The SAB recommends that connectivity be discussed as a continuous phenomenon. However, we recognize that the EPA has chosen to discuss landscape settings discretely in the Report, with separate sections for rivers and streams, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings. This approach is not problematic, as long as the discrete classification is mapped onto the continuous conceptual framework. The integration of the discrete classification and continuous framework could be achieved by adding two panels to the revised Figure 1-1 described above, using the same base block diagram. In the second block diagram, all flowpaths could be removed and the classification system showing the three landscape settings (i.e., rivers and streams, groundwater, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings) could be added. Then, in the third block diagram, the first and second block diagrams could be merged, clearly showing that the continuous phenomena (i.e., the hydrological, chemical, and biological flowpaths) interact across the discrete landscape settings (i.e., connect rivers and streams, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings to one another at the landscape scale). In all three block diagrams, bedrock groundwater systems and flowpaths should be included to illustrate subregional/regional connectivity.

Some editorial or technical corrections are needed in the Report ~~to address various omissions, inconsistencies, and errors in the hydrology section, as well as other sections, of the Report. These~~ and have been identified in the line-by-line preliminary written comments provided by SAB Panel members. Hillslope hydrology is discussed independently here because it is so central to the flowpath framework connecting all parts of the watershed, with water flowing from the "ridge to the reef" and potentially passing through or otherwise interacting with waters and wetlands along the way. The EPA Report should clearly describe the following four pathways through which water flows across the landscape:

1. Infiltration-Excess Overland Flow: This is the overland flow that occurs when the rainfall rate exceeds the infiltration rate, resulting in excess rainfall running overland despite a below-surface water table~~. This flow is also known as Hortonian overland flow because it was first described in the literature by~~ (Horton ~~(~~1945).

2. Saturation-Excess Overland Flow: This is the overland flow that occurs when the water table rises to the surface, so that all additional rainfall runs overland~~. This is also known as Dunne's mechanism because it was first described by~~ (Dunne and Black1970).

3. Interflow: This is rapid lateral flow in the unsaturated zone of soil and rock. Interflow commonly occurs because above a low-permeability layer there are interconnected macropores that intercept and channel rainfall as would a subsurface pipe (e.g., Beven and Germann 1982).

4. Saturated Groundwater Flow: This is the normal saturated groundwater flow, where infiltrating rainfall reaches the water table and then flows laterally along with the general flow in the aquifer.

The Report should further ~~discuss variable source~~ explain how areas ~~and how they~~contributing runoff expand and contract, ~~and therefore change~~changing the way that landscapes connect through storms and seasons (Dunne and Black 1970). ~~Variable source areas have particularly important implications in regards to both infiltration-excess and saturation-excess overland flow, both of which are highly variable~~

Commented [KK157]: (Kolm)

Commented [KK158]: (Kolm)

Commented [AA159]: (Aldous)

Commented [AA160]: (Aldous)

Commented [AA161]: (Aldous)

Commented [M162]: (Murphy) I'm not sure this distinction, which is difficult for non-hydrologists to understand, is important. Just call it Excess Overland Flow and cite the two papers.

~~in space and time. The incomplete discussion of variable source areas is a critical shortcoming of the current version of the Report because it is through variable source area~~The expansion ~~that waters and wetlands~~of runoff producing areas in non-riparian/non-floodplain settings can intermittently or ephemerally ~~become~~change the ~~headward~~ extent of headwater streams (e.g., Dunne 1978; Rains et al. 2006; 2008; Vanderkwaak and Loague 2001)). ~~In other words, these waters and wetlands can functionally change landscape position, from functionally being waters and wetlands in non-riparian/non-floodplain settings under some conditions to functionally being rivers and streams under other conditions.~~ This type of ~~switching behavior is one of the reasons for the SAB recommendation~~variability suggests that connectivity be discussed ~~as a continuous phenomenon.~~within a continuum of runoff producing mechanisms. As previously noted, the EPA has chosen to discuss landscape settings discretely ~~and has organized the Report in sections~~, focusing on rivers and streams, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings. ~~If landscapes are considered to be discrete, it is important to clearly state that;~~ however, the lines delineating these landscape categories are conceptual and ~~/or fluid, i.e., that~~ there ~~are~~is no ~~fixed bright lines between~~scientific consensus on separating the categories.

To provide a better understanding of groundwater connectivity, and the way that groundwater connectivity might vary spatially, the SAB recommends that the EPA also consider using the ASTM D5979-96 Standard Guide for Conceptualization and Characterization of Groundwater Systems (ASTM 1996). ~~This document was developed with funding from the EPA and it provides an effective way to characterize groundwater systems in diverse hydrogeological settings; (e.g.,~~ Kolm et al. 1996). To better characterize regional-scale groundwater connectivity, the SAB recommends that the EPA also consider using findings from the U.S. Geological Survey Regional Aquifer Systems Analysis (RASA) Program. An understanding of regional groundwater flow systems is critical to the understanding of four-dimensional hydrologic connectivity on both the local and regional scales. Understanding groundwater flow in unique hydrogeologic settings, including the Floridan aquifer system (karst systems), the High Plains aquifer system (semi-arid systems), and the Snake River Plain aquifer system (volcanic bedrock systems), is especially important. These and other unique hydrogeological settings are covered by the RASA Program. More information, including a complete list of aquifer systems covered by the RASA Program, can be found in Sun et al. (1991).

The SAB also recommends that the EPA include in the Report additional evidence of biological connectivity. Organismal movement is important for ecosystem function as well as for population dynamics.. Organisms use habitats that are critical to their life-history requirements (i.e., their life cycles cannot be completed without these habitats). These habitats are often dispersed throughout watersheds and organisms move in all directions among ~~the~~these habitats ~~often~~ throughout their life cycles (e.g., Schlosser and Angermeier 1995; Falke ~~et al.~~ and Fausch 2010). Some species maintain populations in downgradient waters but move upstream or laterally to use habitats that are dry seasonally and in some cases are dry several years in a row. Thus, these sometimes-dry habitats can be critical to the biological integrity of downgradient waters. Species using these habitats range across many different taxa, even within fish. There are also significant connections from terrestrial to aquatic ecosystems, particularly among macroinvertibrates. The examples used in the Report tend to focus on only a few taxa, primarily salmon and other anadromous fish species. Many fish restricted to freshwater and many other taxa including invertebrates, amphibians, reptiles, birds, and mammals require these critical habitats and move to access them. When these upstream, lateral, and disconnected habitats are degraded or destroyed, populations decline and species can become threatened or endangered (or otherwise imperiled), or are extirpated entirely., ~~thus,~~ Therefore, connectivity is a key to the biological integrity of

Commented [JH163]: (Harvey) Additional references.

Commented [JM164]: (Meyer) Noting that connectivity should be discussed as a "continuous phenomenon" is different than saying that there is a gradient of connectivity.

Commented [MM165]: (Murphy)

Commented [MM166]: (Murphy)

Commented [DA167]: (Allan) I wonder if the closing claim in his paragraph of no fixed lines between categories is overstated in light of other recommendations to acknowledge a gradient of connectivity.

Commented [DA168]: (Allan) This goes deep into topics of hydrology that I am not familiar with and don't recall receiving much discussion, so I wonder whether a foray into this literature and various aquifer systems really strengthens this report. I think groundwater connectivity definitely has a place in the SAB review and only question how far we should recommend it should go in that direction.

Commented [AA169]: (Aldous)

Commented [D170]: (Patten) do we make sure this thought is applied when we discuss the discrete landscapes? Why have we cited these aquifer systems? Are they good examples when there as some that may be as extensive but not as well known (e.g., flow systems in the Great Basin... carbonate systems) The examples used here are certainly not unique.

Commented [M171]: (Murphy) This comes out of nowhere. We need to state how - - specifically - - the EPA report fails to account for ground water connectivity. Remember, we are not concerned with the impairments of ground water from surface water. It's the other way around.

Commented [MS172]: (Sullivan)

Commented [KF173]: (Fausch)

Commented [MM174]: (Murphy)

downgradient waters. Ignoring these connections can create new threatened and endangered species, especially for highly imperiled vertebrate groups like amphibians, but also invertebrates like mussels that are transported by fish (as glochidia, their larval stage) throughout watersheds.

Recommendations

- The conceptual framework in the Report should be fully described at the beginning of Chapter 3. The framework should have a flowpath focus showing that watersheds are connected from "ridge to reef," and that waters and wetlands in the landscape are therefore connected to downgradient waters by hydrological (surface and subsurface), chemical, and biological flowpaths.

- The conceptual framework in the Report should generally express the importance of climate, geology (surface and subsurface), and relief on flow and transport (e.g., hydrological and chemical connectivity). The resulting three-dimensional structure should show potential surface, near surface, and subsurface pathways, which then can be analyzed in terms of physical, hydrological, chemical, and biological connectivity in four dimensions (i.e., with the temporal dimension included).

- The discrete-landscape classification system should be mapped onto the revised conceptual framework in the Report, with explicit acknowledgment that the classification system serves only as a communication tool. For example, rivers and streams, groundwater, and waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings could be mapped onto the flowpath framework, explicitly showing that connections span these boundaries and that the boundaries are simply convenient ways to bound the landscape for discussion purposes.

- Groundwater connectivity, including regional groundwater connectivity across watershed divides, should be better defined in the Report and described in the context of connectivity between waters and wetlands and downgradient waters.

- Biological connectivity should be better defined in the Report ~~and,~~ described in the context of connectivity between waters and wetlands and downgradient waters~~.~~, and shown to be critical to the biological integrity of these connected waters.

- In presenting this conceptual framework, the Report should also discuss the temporal and spatial significance of the various pathways to downstream water quality.

3.2.4. Revising and Defining the Terminology Used in the Report

With regard to the discrete categories of systems discussed in the Report (i.e., rivers and streams, groundwater, and waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings), the SAB finds that "bidirectional" and "unidirectional" are misleading terms. The Report uses these terms to describe wetlands and open waters with: (1) the potential for non-tidal, bidirectional hydrologic flows with rivers and lakes; or (2) the potential for unidirectional hydrologic flows to rivers and lakes. As previously noted, the four-dimensional nature of connectivity is a foundational aspect of freshwater ecology (e.g., Ward 1989). Bidirectional and unidirectional hydrologic flow certainly describe a key difference among wetland and open water systems. Indeed, in

Commented [AA175]: **(Aldous)** This section needs to propose citable literature

Commented [JT176]: **(Tank)** After finishing the bullets for Section 3.2.3, I felt they did not to match the prior text as closely as one might like.

Commented [LB177]: **(Benda)** The issue of characterizing the strength of connectivity by illustrating it (in words, examples and better yet by diagrams or sketches) for each EPA connectivity component (tributaries, floodplains/riparian areas/channel migration zones, floodplain wetlands and non floodplain wetlands) could be included in this section.

Commented [KK178]: **(Kolm)**

Commented [KK179]: **(Kolm)**

Commented [D180]: **(Patten)** important point

Commented [M181]: **(Murphy)** This is the kind of ground water connectivity EPA needs to clarify.

Commented [MJ182]: **(Josselyn)** Suggested additional recommendation.

Commented [MJ183]: **(Josselyn)** See my comments on this section in the general comments on the draft report.

Commented [KK184]: (Kolm)

some landscape settings, there are two-way fluxes of water and water-borne materials between the landscape and the rivers and streams, while in other landscape settings, there are only one-way fluxes of water and water-borne materials from the landscape to the rivers and streams. Although this is an important difference, it does not adequately characterize the four-dimensional fluxes in both landscapes, most particularly in regards to the movement of biota. The key difference in the respective settings is landscape position, with some waters and wetlands having flood-pulse exchanges with rivers and streams and other waters and wetlands not having flood-pulse exchanges with rivers and streams. Therefore, the SAB recommends that bidirectional wetlands be called "waters and wetlands in riparian/floodplain settings" and unidirectional wetlands be called "waters and wetlands in non-riparian/non-floodplain settings." These terms would employ a commonly understood classification system that is grounded in the literature. This is important not only for communication purposes but also because it is consistent with the peer-reviewed, literature-based focus of the entire Report.

The SAB also finds that use of the term "geographically isolated wetlands" by itself in the Report is problematic. The words "geographically isolated wetlands" technically mean "wetlands isolated in space." However, "geographically isolated wetlands" are defined in the Report to mean "wetlands surrounded by uplands." which the SAB notes could be connected to downstream waters through subsurface connections. These are very different definitions. The SAB acknowledges that the term "geographically isolated wetlands" has been established in the literature, and is commonly used (e.g., Tiner 2003b; 2003c). However, in the flowpath framework recommended by the SAB, there are no truly isolated waters or wetlands. Furthermore, as discussed in other sections of this SAB report, all waters and wetlands are connected over sufficiently long time scales. This conclusion is supported by the review and synthesis of the literature in the EPA Report. In other words, there are no isolated wetlands; rather, all waters and wetlands are connected, differing only in the degree of connection and the degree to which those connections matter to the chemical, physical, and biological integrity of downgradient waters. Therefore, the term "geographically isolated wetlands" runs counter to the continuous flowpath conceptual framework recommended by the SAB. A final point is that the term "geographically isolated wetlands" does not even fit into the current conceptual framework in the Report because the Report explicitly states that geographically isolated wetlands can occur in both riparian/floodplain settings and non-riparian/non-floodplain settings. The SAB therefore recommends that the EPA carefully define "geographically isolated wetlands" in terms of the literature, explain that the term "geographically isolated wetlands" was never meant to imply functional isolation, and then further explain that "geographically isolated wetlands" will not be used as an organizational term in Report. The SAB further recommends that the EPA then remove the term from later sections of the Report or, at the very least, ensure that the term is used consistently and not interchangeably with other terms, as it has been on occasion in the section of the Report on unidirectional wetlands.

EPA needs to consider defining and adding the term 'interrupted stream 'to its discussion of stream categories (Meinzer, 1923; Levick, 2008). Interrupted streams are those that change from ephemeral, intermittent or perennial streams for ecologically distinct reaches. Such streams are common when geological conditions (i.e. change in substrate, faulting, etc.) create rapid changes in aquifer-to-stream recharge/discharge (for example, the San Pedro River in the example or many streams in volcanic terrains (Snake River Plain, Columbia Basin, Hawaiian Islands). Human interaction (ground water pumping, wastewater discharge, etc.) and also create interrupted streams (Rio Grande, Santa Ana River, South Platte River). Connectivity across such interrupting reaches can radically shift, with concomitant alteration in habitat or downstream impact. Although EPA may want to call such streams 'connected,'

Commented [D185]: (Patten) this seems to imply that four dimensional is a biological characteristic ... it is fundamentally a hydrological characteristic on which other phenomenon are connected. At least that is my take on it....

Commented [DA186]: (Allan) See my comments in the general comments on the report. If non-floodplain wetlands is to become the preferred term, I would like to see this section of the SAB report expanded to explain the reasoning

Commented [JH187]: (Harvey)

Commented [LJ188]: (Johnson) Duration and extent.

Commented [KF189]: (Fausch) This sentence is an excellent synthesis of the main point of the entire report, and the relevance of the scientific information to the Clean Water Act itself.

Commented [DA190]: (Allan) I believe we did not reach consensus on this sentence. Perhaps this is the place to insert a sentence to the effect that the strength of connectivity will vary and can only be assessed on a case-by-case basis.

Commented [D191]: (Patten) or necessarily, hydrological isolation as many "isolated wetlands" have a connection to groundwater flows which eventually connect to larger water bodies. Also, there is a whole literature on isolated wetlands so why should they drop the term as it is widely used.

there may be no clear stream bank and bed preserved across the reach and it may be difficult to quantify the ecological importance of the connection.

Recommendations

- The terms "bidirectional" and "unidirectional" do not adequately describe the four-dimensional nature of connectivity. These terms should be replaced in the Report with more commonly understood terms that are grounded in the peer-reviewed literature. The SAB recommends that bidirectional wetlands be called "waters and wetlands in riparian/floodplain settings" and unidirectional wetlands be called "waters and wetlands in non-riparian/non-floodplain settings."

- The term "geographically isolated wetlands" is misleading because it implies isolation in spite of the fact that the flowpath framework implies that all parts of the watershed are connected, and that a fundamental finding of the SAB is that all waters and wetlands are connected at sufficiently long time scales. Therefore, the term "geographically isolated wetlands" should be defined in the Report in terms of the literature. The EPA should explain that use of the term "geographically isolated wetlands" does not imply functional isolation. The SAB recommends that, to the extent possible, the EPA avoid using the term in the Report.

- The term 'interrupted stream' should be defined and used in the discussion of streams where flow is impeded or reduced on the reach scale.

3.2.5. Layers of Complexity in the Conceptual Framework

Once the EPA has described the flowpath framework and explained how the framework is used in the Report, additional layers of complexity (focusing on the issues discussed below) should be represented in the conceptual model. The SAB recognizes that some of these issues are already addressed in various parts of the Report. In those cases, the SAB recommends expanding upon or moving the discussion to the section of the Report that outlines the major concepts underlying the conceptual framework.

Functions

The SAB recommends layering water and wetland function on the flowpath framework. The Report should indicate that each water and wetland performs functions broadly categorized as source, sink, lag, transformation, and refuge, and that the degree to which each function is performed is dependent upon landscape position and related connectivity. The importance of including this in the discussion of the conceptual framework is to explain up front that some hydrological, chemical, and biological functions are ~~enhanced~~enhanced by ~~connectivity~~ connectivity~~and~~ while others are enhanced by relative isolation. ~~This is an important point, one that is implicitly made throughout the report and explicitly made in the section on unidirectional wetlands. Including~~ Including a functions layer in the conceptual framework will help clarify the later discussion of functions that are enhanced by connectivity or relative isolation.

Spatial and Temporal Scales

Spatial and temporal scales are critical aspects of connectivity and the role it plays in the chemical, physical, and biological integrity of downgradient waters. Low-frequency events that affect the chemical, physical, and biological integrity of downgradient waters can be particularly important if the

Commented [MM192]: **(Murphy)** additional text

Commented [D193]: **(Patten)** this idea is bothersome. Should we "define" what we mean... for example, the amount of time that a groundwater flow moves across a basin to connect with rivers????

Commented [DA194]: **(Allan)** This troubles me given that nowher4e to this point has the SAB review indicated what time scale it is considering (and later in the SAB Review the timeline is extended to thousands of years).

Commented [LB195]: **(Benda)** Although true as a general conceptual principle, I think it needs to be qualified somewhere in the EPA Draft Report that in practical (policy) terms (human time frames, land use pressures, limits of understanding, strength of connection), not everything is connected to everything else (as mentioned by more than one of the public commenters, e.g., "everything is connected to everything else" is not useful, including in the context of recent Supreme Court decisions). It is the responsibility of regulatory agencies, using various measures of strength of connectivity, to determine, out of this general scientific principle, what types of connections need to be protected to maintain healthy aquatic ecosystems.

Commented [MM196]: **(Murphy)**

Commented [MJ197]: **(Josselyn)** See my comments on this section in the general comments on the draft report,

Commented [D198]: **(Patten)** is this repetitive? If so, maybe good....

Commented [KF199]: **(Fausch)**

Commented [LJ200]: **(Johnson)**

Commented [D201]: **(Patten)** do we imply here that some waters are truly isolated? Or is this covered by "relative isolation"?

Commented [AA202]: **(Aldous)**

Commented [JM203]: **(Meyer)** The section on spatial and temporal scales that begins here is excellent. Yet I did not see the clear recommendation coming from this in the executive summary.

Commented [DA204]: **(Allan)** Might be an opportunity to clarify some important timeframes of freshwater connectivity, such as 100-year floods (while acknowledging that events on even longer time frames, such as debris movements, can be important). I am uncomfortable with an open-ended temporal scale that might appear to embrace very long time scales.

effects are long--lived or cumulative. Long--lived effects might be best exemplified by debris flows, which are low-frequency events that nevertheless can be an important source of sediment, large clasts, and large woody debris to rivers. Though such debris flows occur infrequently, the consequences can be long lived, and can play important roles in controlling the structure (including connectivity) and function of downgradient waters over the scale of decades. Important cumulative effects might be best exemplified by ephemeral flows in arid landscapes, low-frequency events that may nevertheless provide most of the subsidies to downgradient waters (e.g., Izbicki 2007).

The SAB recommends that the Report compare and contrast the humid eEast and the arid sSouthwest and indicate that downgradient waters in the humid east may get the bulk of their materials though moderate-frequency, moderate-magnitudeare most impacted by frequently recurrent rainfall events while downgradient waters in the arid southwest might get the bulk of their materials through low-frequency, high-magnitudeare primarily shaped by lower frequency rainfall events. The latter are nono less important to the integrity of the downgradient waters, even though their duration may be negligible in comparison. Therefore, the importance of the connectivity is not just a function of the frequency or duration magnitude of the connection. One way to conceptualize this in the Report is by developing a matrix of probability × consequence, which would facilitate a discussion of spaces occupied by given waters and wetlands. This would go a long way toward helping readers better understand the regional context of the spatial and temporal scale of connectivity.

Human Altered Systems

There are few, if any, ecosystems unaltered by humans. The role that these alterations play in the conceptual framework should be addressed explicitly in the Report. Waters and wetlands are "connected" in the sense that they are integrated into the broader hydrological landscape and therefore can play important roles in maintaining the chemical, physical, and biological integrity of downgradient waters. They perform a variety of functions (which are broadly classified in the Report as source, sink, lag, transformation, and refuge functions) at rates that are characteristic to where they are located on the gradient of connectivity. Therefore, downgradient waters might suffer consequences if the degree of connectivity is altered by human activities. Alterations can be of three types—some can directly decrease connectivity (e.g., dams), some can directly increase connectivity (e.g., ditches), and some can indirectly change the magnitude, timing, and/or duration of connectivity (e.g., impervious surfaces in the contributing watershed). Each of these three types of alterations constitute alterations to connectivity and therefore to the chemical, physical, and biological integrity of the downgradient waters.

Flow and Transport Forcings and Regionalization

The SAB finds that the Report fails to provide an adequate framework for considering connectivity in a regional context, especially for states such as Hawaii and Alaska.regions of highly unique ecohydrology. This problem has been identified by a number of public commenters. For example, Alaskan streams and wetlands reflect a climate and solar aspect that is not represented elsewhere and Hawaii is also unlike other part of the US. The arid Southwest experiences a unique combination of climate and geology that conspire to create highly discontinuous flow regimes and riparian ecosystems (RWRD 2008) The EPA therefore should consider expressing flow and transport forcings in terms of Hydrologic-Landscape Regions, or HLRs (Wolock et al. 2004).) or a similar system. This would not represent a large departure from the approach used in the Report because HLRs are fundamentally a function of climate, geology, and relief, which are already recognized as central controls on watershed hydrology. Using HLRs to

Commented [LJ205]: **(Johnson)**

Commented [M206]: **(Murphy)** Actually, the study below showed that the intensity and magnitude of SW storms do not significantly differ from mesic US regions. Osterkamp, W. R., & Friedman, J. M. (2000). The disparity between extreme rainfall events and rare floods— with emphasis on the semi-arid American West. *Hydrological Processes*, *14*(16-17), 2817-2829.

Commented [KF207]: **(Fausch)**

Commented [KF208]: **(Fausch)** I do not fully understand the point of this sentence.

Commented [M209]: **(Murphy)** See my general comments about the model developed in CQ 5a&b

Commented [DA210]: **(Allan)** I think we should discuss what we wish to achieve by acknowledging human alterations, particularly because of our examples. Consider the sentence: "Therefore, downgradient waters might suffer consequences if the degree of connectivity is altered by human activities." Isn't this for the regulatory process to address? And aren't we giving the impression here that perhaps ditches and dams, if they influence connectivity, should be addressed by the CWA? In short, what is the purpose of this section, and does it stray into identifying human actions that should be regulated?

Commented [D211]: **(Patten)** important point

Commented [D212]: **(Patten)** should give a groundwater example here.... all these are surface examples... groundwater withdrawal can decrease connectivity, for example. Since we emphasize groundwater connections in the framework, we should give GW examples.

Commented [SF213]: **(Fennessy)** Add a final sentence that we recommend the Report incorporate the effects of human alterations on connectivity (to ensure we are clear)

Commented [MS214]: **(Sullivan)** I find this subtitle to be a bit awkward

Commented [M215]: **(Murphy)** RWRD (2002), Arid West Water Quality Research Project-Habitat Characterization Project Final Report, Pima County Regional Wastewater Reclamation Department, Tucson, AZ.

consider flow and transport functions would ground the discussion to consistent terminology. The terminology in the Report is currently inconsistent, sometimes referring to climate, geology, and relief, sometimes to climate and watershed characteristics, and other times focusing only on climate. Using the HLRs also would ground the discussion in the Report to peer-reviewed literature on this matter. This could then serve as a means to discuss regionalization, because generalizations are context dependent, i.e., the expressions of chemical, physical, and biological phenomena depend on environmental setting (e.g., climatic, geologic, topographic). Associated with this issue is the fact that much more is known about connectivity in some settings than others. The Report could be improved by explicitly recommending that readers use the HLRs to better understand the relevance of the findings in the document to their respective regions.

Commented [M216]: (Murphy) This sounds like 'selling.'

Aggregate or Cumulative Effects

The aggregate or cumulative effect of many waters and wetlands on the chemical, physical, and biological integrity of downgradient waters is sufficiently important to merit its own subsection in the Report. Mainstem rivers integrate and accumulate the mass, materials, and organisms of numerous waters and wetlands, including tributaries. This is an important concept because the individual effect of any single water or wetland on downgradient waters might be negligible~~at sufficient spatial scale~~, but the cumulative effects of many similarly situated waters and wetlands on downgradient waters might nevertheless still be important. For example, at the scale of a single 200 km^2 watershed, the flow and sediment originating from a single headwater stream with a drainage area of < 1 km^2 may make a minimal contribution to the sediment budget of the mainstem river, but the space-time integration of all headwater streams with drainage areas of < 1 km^2 in the watershed governs the total sediment budget of the mainstem larger river and the resulting in-channel sediment storage, channel morphology, and aquatic habitat.

Commented [D217]: (Patten) surface and groundwater

Commented [MS218]: (Sullivan) I find sufficient spatial scale to be unclear.

Commented [LJ219]: (Johnson) Link this to "integrity" which is an EPA concern.

Commented [AA220]: (Aldous) This section needs specific citations

Cumulative effects could be defined as an emergent property of all headwater streams in the watershed (i.e., a river network statistical attribute). A measurable effect on the integrity of downgradient waters may not be detected if only a small number of headwater streams within a watershed were impacted, whereas there could be substantial and possibly cascading effects on downgradient waters were a larger number of headwater streams impacted. Moreover, the extent of downgradient effects reflects a convolution–both in space and time–of each headwater stream's time-varying flux of mass, materials, and organisms. For example, in a watershed with a 200-year recurrence interval of debris flows on headwater streams, the probability of a debris flow on any given headwater stream in a given year is 0.5% - likely a negligible effect on fish habitat in downgradient waters. However, at the watershed scale, there are hundreds of headwater streams, which means that the annual probability of a debris flow in the "population" of headwater streams is much higher and more likely to substantially affect downgradient fish habitats. ~~Many s~~Studies have been published on these kinds of cumulative effects, such as the aggregate effects of individually occurring debris flows in headwater streams controlling the long tem sediment flux and storage in higher order channels (Benda and Dunne 1997ab) and the cumulative effects of wetlands on watershed hydrology (e.g., Johnston et al. 1990). Therefore, any evaluation of changes to individual waters and wetlands must consider the context of past and ~~planned~~ future (e.g., as a consequence of climate change) alterations of other waters and wetlands in the watershed.

Commented [LJ221]: (Johnson)

Commented [SF222]: (Fennessy) Is this the word we want? Perhaps 'reflects the combination' or 'the aggregation'?

Commented [LB223]: (Benda)

Commented [LJ224]: (Johnson)

Commented [AA225]: (Aldous) This section needs specific citations

Map Scale

The important issue of map resolution is mentioned in several parts of the Report but it needs to be more clearly and thoroughly presented in a separate section, or perhaps in a figure comparing the results of using different technologies. A related topic that could be addressed in the Report is the increasing availability of light detection and ranging (LiDAR) digital elevation models (DEMs) and thus the increasing ability to create more accurate and denser stream networks; this illustrates how new technologies may influence the scientific understanding of connectivity.

It is critical that readers of the Report understand that many databases fail to include small streams and thus do not represent the full extent and magnitude of the river and stream network. For example, Meyer and Wallace (2001) have indicated that in a North Carolina watershed 0.8 km of stream channel are shown on a 1:500,000 scale map whereas 56 km of stream channel are shown on a 1:7200 scale map; only 21% of stream channel length is shown on a 1:24000 scale map in another watershed. The increasing availability of high resolution DEM, including the National Elevation Dataset (NED) 10 m DEM~~. -~~(USGS 2014) and more robust flow routing algorithms means that more accurate stream maps are becoming increasingly available. Thus the ability to predict (and discern) physical, chemical, and biological connections between small and large streams is increasing rapidly. Hence, the degree of connectivity will be determined in some part by ~~advances in~~in the ~~-~~technology used for the analysis.

Recommendations

- Once the EPA has described the flowpath framework and explained how the framework is used in the Report, additional layers of complexity should be represented in the conceptual model. In developing additional layers of complexity, the EPA should focus on the following issues.

  - A water and wetland function framework should be layered on the flowpath framework. EPA should indicate that each water and wetland performs functions broadly categorized as source, sink, lag, transformation, and refuge, with the degree to which each function is performed being dependent upon landscape position and related connectivity.
  - Spatial and temporal scales should be addressed in the discussion of connectivity and the role it plays in the chemical, physical, and biological integrity of downgradient waters. Of particular importance is the potential importance of low-frequency events.
  - The role that human alterations play in the conceptual framework should be addressed explicitly.
  - The EPA should consider expressing forcings in terms of Hydrologic-Landscape Regions, or HLRs (Wolock et al. 2004). This would better enable readers to understand the regional relevance of findings in the Report.
  - The aggregate or cumulative effect of many waters and wetlands on the chemical, physical, and biological integrity of downgradient waters is sufficiently important to merit its own subsection in the Report.
  - The important issue of map resolution is mentioned in several parts of the report, but it should be more clearly and thoroughly presented in a separate section.
  - The Report could more explicitly mention of the issue of evaluating, measuring and predicting the strength of connectivity and thus the significance of connectivity effects could be included. Each component of the EPA's Draft Report (tributaries, floodplains/riparian areas/channel migration zones, floodplain wetlands and non floodplain wetlands) could include discussion covering the issue of strength of connectivity, ideally utilizing a real life example, model simulation or at minimum a conceptualization.

Commented [D226]: (Patten) why does mapping resolution only apply to streams? Why not also wetlands and other water related entities?

Commented [LJ227]: (Johnson)

Commented [LB228]: (Benda) additional item.

3.2.6. Summary and Synthesis of the Conceptual Framework

The SAB finds that Chapter 3 of the Report ends abruptly, with no summary or synthesis of the conceptual framework. The SAB recommends that the EPA consider moving Figure 6.1 (The role of connectivity in maintaining the physical, chemical, and biological integrity of water) to the end of Chapter 3. The figure could then be used as a means of summarizing and synthesizing the conceptual model and explaining how the model guides the way that the ~~agency~~ EPA is thinking about and presenting evidence of connectivity between waters and wetlands and downgradient waters. This figure succinctly shows the role played by connectivity in maintaining the chemical, physical, and biological integrity of downgradient waters and hence would serve this purpose well in Chapter 3.

Recommendation

- A summary and synthesis of the conceptual framework should be added to the end of Chapter 3 of the Report using what is currently Figure 6.1 to frame the discussion.

Commented [MJ229]: (Josselyn) I concur with this recommendation.

3.3. Review of the Literature on Ephemeral, Intermittent, and Perennial Streams

Commented [M230]: (Murphy) I like the organization of this section.

Commented [MJ231]: (Josselyn) See my comments on this section in the general comments on the draft report.

Charge Question 3(a). Chapter 4 of the draft Report reviews the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

The SAB finds that Chapter 4 of the Report is an ~~excellent~~extensive review of the peer reviewed literature that describes the connectivity of headwater streams to downstream waters. The Report documents the current scientific understanding that there are numerous ways that headwater streams are connected to downstream ecosystems and that these connections ~~are~~ can be essential in promoting the physical, chemical, and biological integrity of downstream ecosystems. The connections between headwaters and downstream ecosystems are well established as a foundational concept in stream ecology.

Commented [MM232]: (Murphy)

Commented [MM233]: (Murphy)

The review is based on pertinent literature and is strongly grounded in current science. However, the SAB provides a number of recommendations to improve the literature review in Chapter 4 of the Report. The SAB has also identified additional references to relevant peer reviewed literature that the EPA should consider citing in the Report. As discussed in Section 3.5 of this SAB report, the SAB also recommends that the review of the non-floodplain riparian literature be moved into the Ephemeral, Intermittent, and Perennial Streams section of the EPA Report.

Commented [MS234]: (Sullivan)

3.3.1. Expanding the Review of Hydrologic Exchange Flows between Main Channels and Off Channel Areas

The SAB recommends that the literature review in Chapter 4 of the Report be expanded to include the description of exchanges between main channels and ~~relatively slow moving~~off-channel surface and shallow subsurface waters located at channel margins (e.g., pools, recirculating eddies, subsurface hyporheic flow pats) and in upstream or off-channel areas that may become connected during wet periods (e.g., variable source areas or off-channel sloughs or riparian areas). ~~and surface waters located at channel margins (in pools and in recirculating eddies).~~ The review should include a more complete discussion of the soil-water processes involved and give more attention to spatial and temporal variability that could affect connectivity of streams. The revised text should also include broader discussion of associated biogeochemical transformations that change the form and mobility of dissolved chemicals that affect downstream water quality. The discussion should go beyond solely discussing nitrate removal to include phosphorus removal and examples of fate and transport of contaminants such as toxic metals and organic contaminants. A discussion of the geomorphological control of soil moisture and patch diversity impacts riparian plant communities (Stromberg 2001). The review should also describe how surface-subsurface water interactions affect stream temperature and habitat for fish and other organisms, particularly when surface water flows diminish but subsurface flow is present.

The following references (and others that are similar) should be considered for inclusion in a broader discussion of hyporheic processes: Stromberg 2001, Buffington and Tonina (2009); Karwan and Saiers (2012); Poole et al. (2006); Sawyer, et al. (2011); and Stonedahl et al. (2010).

Recommendations

- The review of hydrologic exchange flows between main channels and off channel areas should be expanded in the Report to include the topics summarized above.

- The additional references identified above (and others that are similar) should be considered for inclusion in the Report for a broader discussion of hyporheic processes.

3.3.2. Expanding the Discussion of Naturally Occurring Chemical Constituents, Contaminants, and Contaminant Transformations

The EPA should expand the discussion in the Report of naturally occurring chemical constituents other than nutrients (i.e., nitrogen and phosphorus), contaminants, and contaminant transformations. The SAB finds that the Report needs a more thorough characterization of upslope (surface and subsurface) effects of geology, soils, and hydrology on overall water chemistry (e.g., conductivity, alkalinity, pH, major cations) and the consequences of altering these upslope processes on downstream water chemistry and associated ecological responses. The role of nutrient spiraling as a demonstration of connections between headwaters and downstream ecosystems is covered in the Report, but the Report could be strengthened if more attention were given to the important transformations that affect mobility, toxicity, and time lags of storage or degree of removal that occurs and how it affects downstream loading of nutrients and contaminants. The Report should also further discuss sediment bound contaminants and their downstream movement and effects on downstream waters.

The following references (and others that are similar) should be considered for inclusion in the discussion of naturally occurring chemical constituents, contaminants and contaminant transformation processes: Baker et al. (2000); Bourg and Bertin (1993); Conant et al. (2004); Doyle et al. (2003); Ensign et al. (2008); Findlay (1995); Fuller and Harvey (2000); Harvey and Fuller (1998); Harvey et al.

Commented [JH235]: (Harvey)

Commented [MM236]: (Murphy)

Commented [MM237]: (Murphy)

Commented [JH238]: (Harvey)

Commented [MM239]: (Murphy)

Commented [M240]: (Murphy) Stromberg, J. C., Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49.1 (2001): 17-34.

Commented [MJ241]: (Josselyn) I concur with the recommendations.

(2013); Hedin et al. (1998); Kim et al. (1992); Kim et al. (1995); Kimball et al. (1994); Lautz and Fanelli (2008); Malcolm et al. (2005); and O'Connor and Harvey (2008).

Recommendations

- The Report should be revised to include discussion of naturally occurring chemical constituents other than nutrients (i.e., nitrogen, phosphorus), contaminants, and to consider nutrients, contaminants, and contaminant transformation processes and the effect of these processes on downstream water quality, if known..

- The additional references identified above, and others that are similar, should be considered for inclusion in the discussion of naturally occurring chemical constituents, contaminants and contaminant transformation processes and the effect of these processes on downstream water quality, if known.

3.3.3. Expanding the Discussion of Factors that Influence Stream Temperature

Stream temperature is an important component of ecosystem integrity because it controls many fundamental ecosystem properties and processes. ~~The SAB finds that the discussion of the role of u~~Upslope factors affecting the relative contributions of surface and shallow and deeper subsurface waters to channel flow and can affect stream temperature an the SAB recommends that discussion of this topic should be expanded. The Report should more explicitly describe the effects of hyporheic flow and storage and resulting lag and attenuation effects that buffer temperature extremes within streams. The discussion of these latter subsurface hyporheic effects should include a comparison to direct groundwater discharge in terms of their comparative effects on stream temperature dynamics. In addition, the treatment of the direct and indirect effects of upstream/upslope riparian shading, channel morphology, and channel network topology on stream temperature should be expanded. The SAB recommends that the Report be revised to expand the discussion of how environmental alterations in channels and upslope areas ~~influence~~ influence connectivity, and thus, stream temperature dynamics. The SAB further recommends that the Report directly address the influence of stream temperature on downstream connectivity. .

The following references (and others that are similar) should be considered for inclusion in the discussion of factors that influence stream temperature: Arrigoni et al. (2008); Hester et al. (2009); and Sawyer et al. (2012).

Recommendations

- The discussion of upslope factors that influence stream temperature should be expanded to include: hyporheic flow and storage, a comparison to groundwater effects on stream temperature; upstream/upslope riparian shading; channel morphology; channel network topology; and environmental/human alterations in upslope areas and channels.

- The Report should explicitly discuss the influence of stream temperature on downstream connectivity.

Commented [JM242]: (Meyer) This bullet says the Report already includes a great deal on nutrients, but then the second half of the bullet says add more about nutrients. Seems contradictory.

Commented [MJ243]: (Josselyn)

Commented [MJ244]: (Josselyn)

Commented [LJ245]: (Johnson) Need to be careful to establish the link between connectivity and stream temperature first, then expand on how changes in connectivity can affect stream temp

Commented [LJ246]: (Johnson)

Commented [MR247]: (Rains) By the time the EPA gets to these reviews, the following paper that explicitly addresses this issue should be published. I'd be happy to provide an advance pre-print for the EPA to review.

Reference: Callahan, M.K., M.C. Rains, J.C. Bellino, C.M. Walker, S.J. Baird, D.F. Whigham, and R.S. King. Accepted Pending Minor Revision, Revised, Resubmitted. Controls on Temperature in Salmonid-Bearing Headwater Streams in Two Common Hydrogeologic Settings, Kenai Peninsula, Alaska. Journal of the American Water Resources Association.

Commented [SF248]: (Fennessy) Could we give an example here to demonstrate our point, for instance temperature effects on the movement of biota?

Commented [LJ249]: (Johnson) Should this be the opposite? Influence of downstream connectivity on stream temperature?

Commented [LJ250]: (Johnson) See above

- The additional references identified above, and others that are similar, should be considered for inclusion in the discussion of factors that influence stream temperature.

3.3.4. Clarifying the Temporal Dynamics of Flow-Related Aspects of Connectivity

The Report does not contain a succinct yet comprehensive paragraph that covers the temporal dynamics of connectivity for headwater streams (e.g., headwaters that connect perennial, intermittent, and ephemeral channels with their variable source areas) and effects on the transport of materials and sediment and on downstream water quality. The SAB finds that Chapter 4 would benefit from a separate section on this topic. Such a section should more fully characterize the temporal dynamics of streamflow (i.e., magnitude, frequency, duration, and timing) and its effects on downstream connectivity. In particular, the section should note that it is the *effect* of flows that determines their importance to downstream connectivity. For example, the Report correctly describes how headwater streams can contribute a large fraction of the water in downstream ecosystems over an annual cycle, even though they are periodically dry. The SAB recommends that the discussion of ecological consequences of flow connections provided by headwater streams be expanded. The SAB also finds that short-term flow connections can be important. That is, connectivity can be highly episodic, but this does not reduce its inherent importance to downstream ecosystems.

More discussion and additional literature citations should be included in the Report to highlight the importance of short duration floods and longer duration droughts and their effects on downstream ecosystems. The SAB recommends that the Report be revised to explicitly recognize the important role of variable hydraulic residence times in river networks and their effects on the storage and transformation of organic matter and nutrients in downstream waters. In addition, the Report should discuss how human alterations affect the temporal dimensions of connectivity (e.g., via water withdrawal or augmentation). Overall, the SAB recommends tightening the entire report to make it clear how intermittent and ephemeral streams are connected in space and time to downstream ecosystems.

The following references (and others that are similar) should be considered for inclusion in the Report to illustrate the ways in which intermittent and ephemeral streams are connected in space and time to downstream ecosystems and the effects of these connections: Boano et al. (2013); Brooks et al. (2006); Constantz (2008); Harvey et al. (2012); and O'Connor et al. (2012); RWRD (2002); and Walker et al. (2005).

Recommendations

- The Report should include a new section that explicitly examines the temporal dynamics of connectivity for headwater streams (e.g., headwaters that connect perennial, intermittent, and ephemeral channels with their variable source areas) and effects on the transport of materials and sediment and on downstream water quality. The new section should note that it is the *effect* of flows that determines their importance to downstream connectivity.

- The Report should be revised to explicitly recognize the important role of variable hydraulic residence time in river networks and its effects on the storage and transformation of organic matter and nutrients in downstream waters.

Commented [M251]: (Murphy) This is a good place to comment on the absence of a discussion of effluent-dependent or dominated waters (EDW). These are a designated use for many Western states and have different ecological functionality than ephemeral or perennial streams (RWRD 2002, Walker et al 2005, Brooks et al 2006). This fact defines a variable ecological connectivity on multiple spatial and temporal scales.

Commented [M252]: (Murphy) RWRD (2002), Arid West Water Quality Research Project-Habitat Characterization Project Final Report, Pima County Regional Wastewater Reclamation Department, Tucson, AZ.

Brooks, B. W., Riley, T. M., & Taylor, R. D. (2006). Water quality of effluent-dominated ecosystems: ecotoxicological, hydrological, and management considerations. Hydrobiologia, 556(1), 365-379.

Walker, D. B., Goforth, C., & Rector, S. (2005). An Exploration of Nutrient and Community Variables in Effluent Dependent Streams in Arizona (pp. 05-09). Arizona Department of Environmental Quality.

Commented [DA253]: (Allan) This section on temporal dynamics provides an opportunity to clarify timescales 9years, decades, centuries).

Commented [LB254]: (Benda) We could include in this paragraph a discussion of the stochastic nature of erosion and sediment flux (and wood debris flux) as a relevant example of the role of temporal dynamics and how it can be handled conceptually and via numerical models (circling back to "Aggregate or Cumulative Effects" of 3.2.5).

Commented [D255]: (Patten) emphasis is not clear

Commented [KF256]: (Fausch) I wonder if this section could be organized better? It jumps from dynamics of streamflow to ecological consequences and then back to short-term highly-episodic flow connections. Likewise, the next paragraph seems a bit disjointed.

Commented [D257]: (Patten) importance of "floods"?? High flows, flash floods? Drought is climatic...do you mean longer duration dry streams?

Commented [D258]: (Patten) withdrawal and augmentation are not necessarily temporal but can be continuous... these topics should be discussed in "framework" as well.

Commented [D259]: (Patten) this is the "bottom line" on this topic... what do we mean by "tightening"?

Commented [MM260]: (Murphy)

Commented [MJ261]: (Josselyn) I concur with these recommendations.

- The Report should include discussion of how human alterations affect the temporal dimensions of connectivity, e.g. via water withdrawal or augmentation~~.~~ and effluent-dependent or dominated stream flow.

- The additional references identified above (and others that are similar) should be considered for inclusion in the Report to illustrate the ways in which intermittent and ephemeral streams are connected in space and time to downstream ecosystems and the effects of these connections.

3.3.5. Strengthening the Review of Biological Connectivity

As previously discussed, the report should be revised to more thoroughly document evidence that biota move throughout the lotic system (e.g., in upstream, lateral, and downstream waters) to use critical habitats and that these movements have strong and important effects on biological integrity. A more thorough treatment of biological connectivity would strengthen Chapter 4 of the report. The following key points should be included in the Chapter:

- Organisms require habitats that are dispersed throughout watersheds (i.e., their populations cannot persist without these habitats), and many species move among these habitats during their life cycles.
- Some species maintain populations in downstream receiving waters, but move upstream or laterally to use habitats that are dry seasonally and in some cases are dry several years in a row. Thus, these intermittent or ephemeral habitats often can be critical to the biological integrity of downstream waters.
- These mobile species ~~range across~~include many different taxa, even within fish, and ~~include~~ encompass many more than those identified in the Report, which focuses largely on salmon and other anadromous fish. Many fish living solely in freshwater, and many other taxa including amphibians, reptiles, birds, mammals, and important invertebrates, require these habitats and move to access them.
- Data from comparative studies and experiments show that these animal populations decline or are extirpated entirely when upstream, lateral, and disconnected habitats are degraded or destroyed~~.~~, or the connections are lost (e.g., owing to constructed barriers). Thus, connectivity to these habitats is a key to the biological integrity of downstream waters. Dam and dam-removal literature may be helpful to illustrate this point.
- Ignoring these critical habitat connections can create new threatened and endangered species, especially for highly imperiled vertebrate groups like amphibians, but also highly imperiled groups of invertebrates like mussels whose larvae are transported throughout watersheds by their fish hosts.

Recommendation

- The Report should more thoroughly document evidence that biota move throughout the lotic system (e.g., in upstream, lateral, and downstream waters) in order to use critical habitats and that these movements have strong and important effects on biological integrity of downstream waters, as detailed in the points above.

3.3.6. Review of the Human-Modified Headwater Stream Literature

Commented [MM262]: (Murphy)

Commented [M263]: (Murphy) A caution is needed here that we are only concerned with flow to and impact on WUSA not on contributions of WUSA to upland communities, except where there is feedback to the stream..

Commented [SF264]: (Fennessy) Some wetlands are best classified as lentic, we may want to rephrase this to make sure both types of systems are covered

Commented [D265]: (Patten) this is a shift in text formatting... but OK

Commented [KF266]: (Fausch)

Commented [KF267]: (Fausch)

Commented [MS268]: (Sullivan)

Commented [MJ269]: (Josselyn) I concur with this recommendation.

Commented [AA270]: (Aldous) This section needs specific citations

Commented [M271]: (Murphy) Another spot for noting the unusual flow properties and chemistry of effluent dependent waters.

Commented [MJ272]: (Josselyn) See my comments on this section in the general comments on the draft report.

As previously mentioned, the SAB finds that the Report lacks references to the literature on human-modified headwater streams. This literature should be included in the Report in order to provide information about the consequences of alterations of headwater systems to water quality and biota of downstream ecosystems. Many headwater stream ecosystems are altered by land use change and human activity that often disrupts connectivity; the effects of such disruptions illustrate the importance of headwaters to downstream areas in various landscapes. The downstream impacts of increased imperviousness are well studied (e.g., Nagy et al. 2011). The SAB recommends that connectivity be discussed within the context of the following human alterations: agricultural ditches and tile drains, urban lined channels and buried streams, removal of riparian trees, cattle grazing, gravel mining, channel diversions, low-head dams, grade control structures, stream restoration, and effluent dominated streams. Some of these alterations reduce connections to downstream waters, but some alterations increase the frequency and magnitude of connections. In addition, human-altered or even human-created streams may provide significant ecological functions that can affect downstream waters. A succinct discussion of the downstream consequences of stream restoration would also strengthen the Report.

The following references (and others that are similar) should be considered for inclusion in the Report to illustrate the effects of human alterations to headwater streams: Booth (1990); Bull and Scott (1974); Chin and Gregory (2001); Doyle et al. (2000); Graf (2006); Gregory (2006); Faulkner (2004); Horner et al (2001); Lautz et al. (2008); and O'Connor et al. (2010); Paul and Meyer (2001); Schumm et al (1994); Williams and Wolman (1984); and Wohl (2005).

Recommendations

- The draft Report should be revised to include information about the consequences of alteration of headwater systems to water quality and biota of downstream ecosystems. These revisions should include discussion of the ~~positive and negative~~ effects~~effect~~ of: agricultural ditches and tile drains, urban lined channels and buried streams, removal of riparian trees, cattle grazing, gravel mining, channel diversions, lowhead dams, grade control structures, stream restoration, and effluent dominated streams.

- The additional references identified above, and others that are similar, should be considered for inclusion in the Report in order to illustrate the effects of human alterations to headwater streams.

3.3.7. Highlighting the Role of Headwater Streams in Aggregate and Cumulative Effects On Downstream Ecosystems

The SAB recommends that a new section on the role of headwater streams in aggregate and cumulative effects on downstream ecosystems be added to Chapter 4 of the Report. This new section should draw upon the large body of literature on cumulative watershed effects of land use, based on both modeling and empirical studies. In addition, the existing section on watershed modeling should be improved by expanding the discussion to include results from models beyond the SPARROW model (SPAtially Referenced Regressions On Watershed attributes).

The following references (and others that are similar) should be considered for inclusion in the Report to document the role of headwater streams in aggregate and cumulative effects on downstream ecosystems: Alexander et al. (2009); Böhlke et al. (2009); and Helton et al. (2011).

Commented [DA273]: (Allan) The SAB review suggests a review of all the ways that human activities alter connectivity, which is a large task. Perhaps a table could be developed that listed main categories of alterations to connectivity. A useful citation is Blann, K. L., J. Anderson, G. Sands, and B. Vondracek. 2009. Effects of agricultural drainage on aquatic ecosystems: a review. Critical Reviews in Environmental Science and Technology 39(11):909-1001.

Commented [LB274]: (Benda) I would add to the list of human influences "accelerated erosion, sediment transport and storage".

Commented [LK275]: (Kalin)

Commented [MS276]: (Sullivan)

Commented [SF277]: (Fennessy) This is a comprehensive list, that is also fairly long list in terms of material added to the report. Perhaps we could suggest a table that would summarize the primary impacts of these human alterations on connectivity.

Commented [LJ278]: (Johnson) Might be helpful to provide an example.

Commented [MR279]: (Rains) Water quantity, too, right?

Commented [D280]: (Patten) water quantity and quality,

Commented [JT281]: (Tank) This bullet on effects of human alterations to headwater streams should be clarified to focus on the effects of human alterations on "connectivity of headwater streams", with the goal being to keep the Report focused on the question of connectivity.

Commented [MJ282]: (Josselyn) I think that it is important for the SAB Report to document the limitations of the SPARROW model and to recommend that, based on the availability of scientific information beyond that already reported, that this section be expanded. The references cited are primarily related to nitrogen dynamics. It may be necessary for the Panel members to provide additional documentation of references to the EPA beyond that supplied.

Commented [GA283]: (Ali) The subgroup working on streams recommends that a separate section be added to chapter 4 of the EPA report to address aggregate and cumulative effects. Other subgroups have also recommended further discussion but not necessarily in separate Report sections. For consistency purposes I would suggest that all subgroups align themselves with the streams subgroup and recommend that all chapters of the EPA report include stand alone sections to discuss aggregation.

Commented [D284]: (Patten) recommended in framework...should that be referenced here?

Recommendations

- A new section on aggregate and cumulative effects of headwater streams on downstream ecosystems should be added to Chapter 4 of the Report.

- The findings of the modeling and empirical studies on the cumulative effects of land use on water quality should be summarized in the Report.

- The modeling section of the Report should be expanded to include results from additional models.

- The additional references identified above, and others that are similar, should be considered for inclusion in the Report to document the aggregate and cumulative effects to downstream connectivity.

3.3.8. Expanding the Discussion of the Effects of Streamside Vegetation on Stream Ecosystems

The SAB notes that many of the beneficial ecological effects of streamside vegetation are not exclusively associated with riparian wetland function (e.g., effects of ~~leaf litter~~ inputs of leaf litter~~inputs~~ and terrestrial insects to downstream food resources, effects of woody debris on channel morphology, sediment and organic matter storage, hydrologic retention, and modulation of stream temperature, among others). These beneficial effects occur along the entire longitudinal profile, but are especially important to headwater streams. The SAB recommends that the draft Report be revised to expand the discussion of the effects of streamside vegetation on stream ecosystems.

Recommendation

- The Report should be revised and additional references should be added to expand the discussion of the effects of streamside vegetation on stream ecosystems.

3.3.9 Food-web Connections from Riparian Zones to Streams that Support Aquatic Organisms

The SAB recommends adding a new section to the Report to thoroughly address the importance of food-web connections from riparian zones to streams that support aquatic organisms. The Report focuses on strictly aquatic connections~~, however~~. However, organisms that define the biological integrity of downstream waters are embedded in food webs and these food webs transcend aquatic-terrestrial boundaries. The following key points should be included in the new text:

- Streams receive organic matter in the form of leaves, wood, and other plant litter from riparian vegetation, and these supply carbon and nutrients to biota ranging from microbes to invertebrates, which in turn feed larger invertebrates, fish, amphibians, reptiles, birds, and mammals. Terrestrial carbon is also an essential component of the microbial food web. ~~-~~
- Streams also receive terrestrial invertebrates, which are used directly as prey by fish and amphibians, either in the same reach, or after flowing downstream from headwaters into reaches that support these predators.
- ~~Linkages~~ These linkages between riparian zones and streams are critical to maintaining the biological integrity of the Nation's waters, and data from comparative studies and experiments

Commented [D285]: (Patten) also in framework.... see above.

Commented [M286]: (Murphy) I think this just another part of Section 3.3.5

Commented [DA287]: (Allan) This section sounds like it is intended to describe the benefits of an intact riparian zone. I wonder if that is off-topic. If so, the subsequent section on subsidies and interchanges may be of topic as well.

Commented [KF288]: (Fausch)

Commented [D289]: (Patten) does this need to be tied to "connectivity" in some way other than just function of riparian veg?

Commented [MS290]: (Sullivan) This recommendation should be consistent with the recommendation presented in the following section of the Panel's Report (3.5) related to moving the non-floodplain riparian literature to this section.

Commented [MJ291]: (Josselyn) I disagree with this recommendation as it is not germane to the issue of wetland connectivity, but rather a function of non-wetland riparian forests input. Upland forests also contribute leaf litter, woody debris, and other organic inputs. However, the Report's focus is not on ecosystem function, but on connectivity of wetlands and streams to downstream waters and therefore the inclusion of non-wetland inputs would considerably expand the EPA's efforts and would not be relevant to the purpose of the Report.

Commented [M292]: (Murphy) Same as 3.3.8 combine with 3.3.5, or at least 3.3.8.

Commented [D293]: (Patten) justify this statement relative to connectivity???? are food web connections critical as connectivity between any component of a riparian zone and an adjacent river???? The points given are somewhat circular argument.

Commented [SF294]: (Fennessy) Word choice? Perhaps they cross boundaries?

Commented [SF295]: (Fennessy) There is information on this topic in Chapter 5 of the Report, and there the SAB recommends that the text specific to riparian zones be move to chapter 4 (i.e., here). We should mirror the text, for instance on page 33, lined 20-25, in this section. At minimum, the Report text that we propose be moved will serve as a starting point for this suggestion, and our recommendations will be consistent.

Commented [LJ296]: (Johnson)

Commented [KF297]: (Fausch)

support the generalization that cutting off these connections can cause emigration or extirpation of organisms that rely on food web connections from streams to riparian zones.

– Finally, food webs integrate aquatic and terrestrial landscapes and therefore provide a useful lens through which to view connectivity in aquatic ecosystems.

Recommendations

- The SAB recommends adding a new section (with additional references such as Baxter et al. 2005 and Wipfli and Baxter 2010) to the Report to thoroughly document the importance of bidirectional, reciprocal food-web connections ~~from~~ between riparian zones ~~to~~ and streams; the new section should discuss the points itemized above.

3.3.10. Clarifying How Case Studies Were Selected

As previously discussed, the SAB recommends that text be added to the Report to clarify how the case studies were selected. In addition, a case study that focuses on human-dominated systems should be added to the Report in order to include information about the effect of human-dominated systems on downstream waters. For example, the Rio Grande case study on arid rivers provides excellent examples of human-modified systems and its description of human effects could be expanded. Other examples include the Baltimore and Central Arizona Long Term Ecological Research Projects (Cary Institute of Ecosystem Studies 2014; Long Term Ecological Research Network 2014). The SAB notes that the San Pedro River example is never mentioned or interpreted in the rest of the EPA report.

Recommendations

- The Report text should explain the rationale for selecting case studies.

- The Report should contain a case study that illustrates the downstream effects of human-modified systems, perhaps through revising the Rio Grande case study. The Baltimore and Central Arizona Long Term Ecological Research Projects are good examples (Cary Institute of Ecosystem Studies 2014; Long Term Ecological Research Network 2014).

3.3.11. Clarifying the Report Findings Concerning the Strength or Degree of Downstream Connectivity

The SAB recommends that the Report text be revised to address the strength or degree of downstream connectivity. At a minimum, this clarification should be addressed in the Chapter 4 section on headwater streams, but the topic should also be clarified throughout the Report. In particular, the SAB finds that the Report needs a more focused discussion of the relative strength/degree of connectivity of intermittent and ephemeral streams and their variable source areas. This could be achieved through a discussion of the frequency, duration, and magnitude of surface and subsurface connections. It is important to note that subsurface flows often persist after surface flows wane; further, these subsurface flows may provide important connectivity functions from ephemeral streams to downstream waters. In addition, as previously discussed, even ephemeral streams and short duration surface water connections in source water areas may have substantial effects on the ~~chemistry~~ chemical and ~~biology~~ biological integrity of downstream waters.

Commented [MJ298]: (Josselyn) I disagree with this recommendation for similar reasons as stated above.

Commented [KF299]: (Fausch)

Commented [MS300]: (Sullivan)

Commented [AA301]: (Aldous) This section needs specific citations

Commented [LK302]: (Kalin) The Baltimore and Central Arizona LTERs would have been good examples for human dominated systems.

Commented [MJ303]: (Josselyn) I believe that this was covered in a previous section of the draft report.

Commented [LK304]: (Kalin)

Commented [MM305]: (Murphy)

Commented [D306]: (Patten) how many systems are NOT human modified... are we asking for the obvious? and why is the Rio Grande such a good or distinct example?

Commented [M307]: (Murphy) Again, this falls back and should connect tightly to the conceptual model and the frequency, duration, and magnitude discussions elsewhere.

Commented [D308]: (Patten) use both any place that ephemeral is mentioned

Commented [D309]: (Patten) and intermittent streams

Commented [KF310]: (Fausch)

On the other hand, in the arid Southwest, high evaporative losses and coarse, permeable stream beds can result in ephemeral streams that experience enormous transmission losses (Graf 1988, Osterkamp et al. 1994, Goodrich et al. 2004). This fact combined with the spatial distribution of rainfall, soil texture and vegetation creates conditions where runoff in headwaters streams might not persist throughout the watershed to bottomland waters (Hernandez et al. 2000, Stratton et al. 2009).

The SAB recommends that the following reference (and others that are similar) be considered for inclusion in the Report to document the strength or degree of downstream connectivity: Larsen et al. (2012).

Recommendations

- The SAB recommends that the degree/strength of downstream connections be highlighted or discussed in each major subsection of Chapter 4 and in other sections of the Report (e.g. for subsections on temperature, chemical, and biological connections).

- The additional reference identified above (and others that are similar) should be considered for inclusion in the Report to document the strength or degree of downstream connectivity.

3.3.12. Role of Groundwater and Sediment

The physical, chemical, and biological effects and quantification of groundwater flow, as related to surface water connectivity, need to be included in the discussions, and should be included (referenced) and supported by an expanded Conceptual Model Chapter. Discussions on sediment need to be coordinated with the geology and sedimentology literature, which has been established long before most of the literature cited in this document. There are 3 types of sediment described, characterized, and quantified in the geologic and hydrology literature: dissolved, suspended, and bedload (based on type of movement and size). Combining the sedimentology literature with the current literature, including contaminant transport, is recommended to establish connectivity in these surface water systems.

3.4. Review of the Findings and Conclusions Concerning Ephemeral, Intermittent, and Perennial Streams

Charge Question 3(b). Conclusion (1) in section 1.4.1 of the draft Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3 (a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please note alternative wordings for any conclusions and findings that are not fully supported.

Conclusion 1 in Section 1.4.1 of the Report states that: *The scientific literature demonstrates that streams, individually or cumulatively, exert a strong influence on the character and functioning of downstream waters.* The Report further states that: *All tributary streams, including perennial, intermittent, and ephemeral streams, are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits where water and other materials are concentrated, mixed, transformed, and transported.* The SAB finds that the Report provides ~~strong~~ scientific support for these conclusions and related findings~~.~~, in some specific cases; however, it does not demonstrate that absolute connectivity exists in 'all' tributary streams. Rather, the literature indicates

Commented [M311]: (Murphy) Osterkamp, W. R., L. J. Lane, and C. S. Savard. "RECHARGE ESTIMATES USING A GEOMORPHIC/ DISTRIBUTED-PARAMETER SIMULATION APPROACH, AMARGOSA RWER BASIN1." JAWRA Journal of the American Water Resources Association 30, no. 3 (1994): 493-507.

Graf, W. L. (1988). Fluvial processes in dryland rivers (Vol. 3). New York: Springer.

Goodrich, D. C., Williams, D. G., Unkrich, C. L., Hogan, J. F., Scott, R. L., Hultine, K. R., ... & Miller, S. (2004). Comparison of methods to estimate ephemeral channel recharge, Walnut Gulch, San Pedro River basin, Arizona. Water Science and Application, 9, 77-99.

Commented [M312]: (Murphy) Hernandez, M., Miller, S. N., Goodrich, D. C., Goff, B. F., Kepner, W. G., Edmonds, C. M., & Jones, K. B. (2000). Modeling runoff response to land cover and rainfall spatial variability in semi-arid watersheds. In Monitoring Ecological Condition in the Western United States (pp. 285-298). Springer Netherlands.

Stratton, B. T., Sridhar, V., Gribb, M. M., McNamara, J. P., & Narasimhan, B. (2009). Modeling the Spatially Varying Water Balance Processes in a Semiarid Mountainous Watershed of Idaho1. JAWRA Journal of the American Water Resources Association, 45(6), 1390-1408.

Commented [MM313]: (Murphy)

Commented [DA314]: (Allan) Strength of downsteam connectivity needs to be addressed for biology as well as hydrology. Mark Wipfli's papers will be helpful.

Commented [D315]: (Patten) the above discussion emphasizes ephemeral and intermittent ...so should recommendations mention them.

Commented [KK316]: (Kolm) Recommend including a new section.

Commented [KK317]: (Kolm)

Commented [M318]: (Murphy) This is actually one of the clearer of the sections but there is a lot of duplication of discussion in the CQ 3,4,5 b sections, making for tedious reading and confusion. There should be more back referencing in the 'b' sections of the SAB report to the appropriate 'a'sections. I would prefer that a and b just be merged for each CQ unless that is not permitted by EPA.

Commented [M319]: (Murphy) Accepting this conclusion without qualification is not consistent with the rest of the SAB Report or the deliberation last December.

that a spectrum of ecological connectivity exists in all streams that are a function of the frequency, magnitude and duration of physical, chemical and biological processes. The SAB strongly supports the current emphasis in this Section on the importance of considering cumulative impacts and recommends minor but nevertheless important changes in the conclusions and findings in Section 1.4.1.

The Report should be revised so that the conclusions and findings in Section 1.4.1 are clearly linked to the foundational concept that connectivity is expressed in four dimensions (i.e., three dimensional space, plus time) within the context of a catchment. The SAB recommends that the conclusions emphasize not only hydrologic linkages, but also include biogeochemical transformations and diverse biological connections. The text in Section 4.6 of the Report, "Synthesis and Implications," (p. 4-35) could be improved through the use of bullets that would highlight the main findings. This would underscore the key functions summarized in Table 4.1 which outline the five key stream functions and their effect on downstream waters: sources, sinks, refuges, transformations, and lags. The SAB recommends adding connectivity itself to Table 4.1, perhaps using biological connections as an example. In addition, the Report's five key functions and linkages (six if connectivity is included) should be reiterated succinctly[1] and consistently across the relevant Report chapters. These are Sections 4.6, "Streams: Synthesis and Implications" (p. 4-35); Section 1.4.1, "Key Findings" (p.1-7); and Section 6.1, "Major Conclusions" (p. 6-1). At present, these summaries vary in content, length, presentation style, and number of literature citations and, most importantly, these inconsistencies obscure the Report's conclusions.

Recommendations

- The conclusions in Section 1.4.1 of the Report should be clearly linked to the foundational concept that connectivity is expressed in four dimensions (i.e., three dimensional space plus time) within the context of a catchment.
- The conclusions in Section 1.4.1 should emphasize not only hydrologic linkages, but also include biogeochemical transformations and diverse biological connections.
- Bullet points should be used to highlight main findings in the text on "Synthesis and Implications."
- "Connectivity" should be added to Table 4.1 using biological connections as an example.
- The Report's key functions and linkages should be succinctly and consistently summarized across all the relevant Report chapters.

3.4.1. Recommendations to Strengthen the Findings and Conclusions Concerning Ephemeral, Intermittent, and Perennial Streams

The SAB recommends that the Report be revised to strengthen the findings and conclusions concerning ephemeral, intermittent, and perennial streams by addressing the specific issues discussed below.

Connectivity, Boundaries and Linkages

[1] The summary should not include reference to literature already cited in the Report.

Commented [MM320]: **(Murphy)**

Commented [D321]: **(Patten)** would use of hydrological connections here more emphasize what most readers consider the main connections?

Commented [LJ322]: **(Johnson)** writing and

Commented [D323]: **(Patten)** why biological ...see above comment

Commented [SF324]: **(Fennessy)** Do we consider connectivity a function? Or the condition that allows the 5 key functions in Table 4.1.

Commented [MJ325]: **(Josselyn)** See my comments on this section in the general comments on the draft report.

The SAB recommends that the statements in the Report that support conclusions about the connectivity of streams should be stated in quantitative terms wherever possible (For example: "of X studies, X% support the conclusion of connectivity.")

The SAB also recommends that the text of the Report be revised to provide better definition of boundaries (e.g., transitions between uplands and headwaters) and acknowledge where boundaries are difficult to define. The report should also better define and emphasize key linkages and exchanges that influence connectivity (e.g., groundwater-surface water interactions, flooding or other episodic events, and the influence of riparian zones) and how these linkages influence biota and food webs and vice versa. For example, the first sentence in Section 4.6, "Streams: Synthesis and Implications," should be revised to state ~~that~~ "A substantial body of evidence unequivocally demonstrates connectivity *above and below ground.*" The conclusions should also reiterate how these linkages and exchanges influence physical, chemical, and biological connectivity with downstream systems.

The SAB finds that connectivity linkages that occur during flooding are not well-represented in the conclusions. Conversely, the lack of connectivity during drought is poorly discussed. Although drought is a natural disturbance, its effects can be exacerbated by human activities (i.e., water extraction; wetland drainage) with possible profound impacts on connectivity. In addition, the SAB recommends that text be added to the Report to explain ~~how~~ hydrologic connectivity where surface water sustains aquifers~~.~~ in some environments, and aquifers sustain streams in other environments. Alluvial systems in the southwest and karst systems in the eastern U.S. should be used as examples. The perennial streams in the Colorado Plateau and the Rocky Mountain and High Plains systems are examples of aquifers sustaining streams. Floodplains locally and regionally may function in one or both directions; particularly with spring runoff/flooding (groundwater recharge and water table rise) versus fall baseflow (groundwater discharge and water table lowering).

Ephemeral Streams

The Report concludes that existing evidence supports a sufficient link between ephemeral streams and downstream systems. The SAB finds that this conclusion could be strengthened in three ways: (1) by adding text that describes spatial and temporal variation in linkages of ephemeral streams with downstream waters; (2) by summarizing existing evidence of the frequency/duration of these connections; and (3) by identifying where further research is needed. For example, the Report currently emphasizes the important role of variable source areas (e.g., swales) in downstream connectivity; this role should be reiterated in the conclusions. In addition, the conclusions in the Report should emphasize that dynamic groundwater-surface water connections not only maintain the ecological integrity of ephemeral streams, but also connect them structurally and functionally to downstream waters, whether or not the upstream channels are perennial. Finally, the SAB recommends that the conclusions concerning ephemeral streams be strengthened by clarifying how and when ephemeral headwaters provide critical habitat and corridors for biota to move among their habitats.

Chemical Connectivity and Nutrients

The SAB finds that the summary of chemical functions that has been included in the Report could be strengthened by adding details about how headwater streams influence sediment-bound nutrients, dissolved organic matter (DOM), and contaminants; the text now focuses primarily on nitrogen, with detailed examples provided only for nitrate as it related to denitrification.

Commented [GA326]: (Ali) A similar recommendation should be made by the "unidirectional wetlands" subgroup for Section 5.4 of the EPA Report.

Commented [LJ327]: (Johnson)

Commented [KK328]: (Kolm)

Commented [KK329]: (Kolm)

Commented [LJ330]: (Johnson)

Commented [D331]: (Patten) that commonly are connected to habitats associated with downstream rivers.

The SAB also finds that the Chapter 4 of the Report is currently too focused on headwaters as hotspots for uptake and transformation of nitrogen; more breadth across solutes should be added. The text should also be revised to include nutrient removal processes in the discussion on the importance of nutrient spiraling because both assimilatory and dissimilatory processes are important. Currently, the text focuses on the role of denitrification processes in removing nitrate-N from streams.

Treatment of Uncertainty

The SAB recommends that the authors consider summarizing and displaying the Report's conclusions in matrix form. A well designed matrix could have several advantages as it would better communicate: the evidence underlying each conclusion, the uncertainty for a given conclusion across different functions (i.e., source, sink, refuge, lag, and transformation), and the confidence in conclusions across different system types (e.g., streams versus adjacent wetlands). The SAB also recommends including in the Report brief characterizations of the temporal or spatial scales over which given functions or phenomena occur and their sizes, intensities, and effects. Use of graphical methods to convey the level of confidence in the Report's conclusions, e.g., similar to Intergovernmental Program on Climate Change report (IPCC 2007) would also help to better communicate findings. For example, conclusions drawn at broad regional scales could have a high level of certainty and conclusions drawn for an individual site at a local scale could have lower certainty.

Case Studies and Context

The SAB finds that it is difficult to discern the intended illustrative points of the Report's case studies within the broader discussion of streams in Chapter 4. The SAB recommends that the Report be revised to clarify the intended use of the case studies, whether as examples of common situations or examples of unusual extremes. For example, in the case study on prairie streams, the key point was how human alterations influence connectivity. The SAB also finds that some case study conclusions appear to be overreaching (e.g., the arid streams example) and are not presented within the context of geographic differences (e.g., flow in arid streams in urban environments can be dominated by waste treatment effluent, such as for Rio Grande River at Albuquerque, New Mexico). Thus, for this case, real-world management scenarios can contrast greatly with the situations described in the case study for arid streams.

The SAB also recommends that the EPA develop an alternative case study framework that uses hydrology as a unifying theme. For example, stream flow is a function of runoff, which is in turn a function of ~~weather~~ climate and underlying geology, all of which vary regionally. For the summary conclusions, the SAB recommends that the authors consider distinguishing flow-, geology- and climate~~weather~~-dependent conclusions from the broader more general conclusions. The SAB finds that conclusions for the case studies could be improved by being explicit about how human activities alter (both increase and decrease) above and below ground connectivity of streams with downstream waters, ideally through the use of specific examples (e.g., perhaps using the Report's existing case studies). The SAB notes that each case study has its own unique bulleted list of conclusions, which makes it difficult to draw conclusions across the case studies or to relate individual case studies to the Report's general conclusions.

Consistent Statement of Conclusions throughout the Text

Commented [MS332]: (Sullivan) Highlighting the key point of each case study would make them more impactful. I suggest emphasizing this point in the Panel's report.

Commented [D333]: (Patten) NOT clear what the point(s) are.

Commented [AA334]: (Aldous)

Commented [LK335]: (Kalin) I am not sure I understand what is recommended here.

The SAB also notes that it is essential that descriptions of functions and linkages in the Report be consistently and succinctly stated in Section 4.6 "Streams: Synthesis and Implications," (pages 4-35 and 4-36) and Section 1.4.

Recommendations

- Statements in the Report that support conclusions about the connectivity of streams should be stated in quantitative terms wherever possible.

- The EPA should consider summarizing and displaying the Report's conclusions in matrix form and including brief characterizations of the temporal or spatial scales over which given functions or phenomena occur, and their sizes, intensities, and effects.

- The text of the Report should be revised to describe system boundaries, e.g., transitions between uplands and headwaters, and to provide better definition of the boundaries of a stream.

- The report should better define and emphasize key linkages and exchanges that affect connectivity (such as groundwater-surface water interactions, flooding or other episodic events, and the influence of riparian zones) and how these linkages influence biota and food webs and vice versa. The conclusions in the Report should also reiterate how these linkages and exchanges influence physical, chemical, and biological connectivity with downstream systems.

- Text should be added to the Report to explain how hydrologic connectivity sustains aquifers. Alluvial systems in the southwest and karst systems in the eastern U.S. should be used as examples.

- The conclusions concerning ephemeral streams should be strengthened by: (1) adding text that describes spatial and temporal variations in linkages of ephemeral streams with downstream waters; (2) summarizing existing evidence of the frequency of these connections; (3) identifying where further research needed; and (4) clarifying how and when ephemeral headwaters provide critical habitat and corridors for biota to move among their habitats.

- The summary of chemical functions that has been included in the Report should include details about the ways that headwater streams influence sediment-bound nutrients, dissolved organic matter (DOM), and contaminants.

- ~~The EPA should consider summarizing and displaying the Report's conclusions in matrix form and including brief characterizations of the temporal or spatial scales over which given functions or phenomena occur, and their sizes, intensities, and effects.~~

- The intended use of the case studies should be clarified in the Report. An alternative framework for the case studies could be used in which hydrology is a unifying theme. In the case studies, the EPA could also consider distinguishing flow, geology- and ~~weather-~~climate-dependent conclusions from broader general conclusions.

Commented [LJ336]: **(Johnson)** this is a long list of recommendations; are they grouped appropriately?

Commented [LJ337]: Reorder this so that items that represent the entire document or section are listed prominently at the top.

Commented [MJ338]: **(Josselyn)** This recommendation should include a statement that "The Report should analyze the scientific literature and discuss the differences in connectivity within the floodplain under various flood regimes, from 1 to 100 year floods. There may be significant differences in the degree of connectivity that should be evaluated".

Commented [D339]: **(Patten)** two way connection, not just sustaining aquifer... aquifer sustains baseflows

Commented [MJ340]: **(Josselyn)** This recommendation should be clarified because aquifer replenishment is a broad category and may not be relevant to downstream water quality. I suggest that it should only be discussed in terms of aquifers that address downstream water quality, not deep basins.

Commented [D341]: **(Patten)** move among and with their habitats associated with downstream waters

Commented [AA342]: **(Aldous)**

- Descriptions of functions and linkages should be consistently and succinctly stated in Section 4.6 (pages 4-35 and 4-36) of the Report "Streams: Synthesis and Implications" and Section 1.4.

3.5. Review of the Literature on Waters and Wetlands in Riparian/Floodplain Settings

Charge Question 4(a). Section 5.3 of the Report reviews the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

The SAB was asked to comment on whether the Report includes the most recent peer reviewed literature with respect to wetlands and open waters subject to non-tidal bidirectional hydrologic flows with rivers and lakes, and whether the literature has been correctly summarized and characterized. The SAB generally finds that the literature synthesis on waters and wetlands in riparian/floodplain settings has been ~~correctly~~ well summarized and characterized in the Report. The literature review substantiates the conclusion that, in an overwhelming number of cases, floodplains, riparian areas, and waters and wetlands in riparian/floodplain settings support the physical, hydrological, chemical, and biological integrity of downstream waters. However, as further discussed, additional emphasis, discussion, and reorganization of the information presented (and in some cases review of more recent and diverse literature) are needed in the Report to address the significance of ~~bidirectional~~ multi-dimensional connectivity.

3.5.1. Structure of Section 5.3 of the Report

Chapter 5 of the Report addresses the subject of physical, chemical, and biological connections of wetlands to rivers. Section 5.3 focuses on riparian and floodplain wetlands and covers a wealth of topics. The Section could be strengthened by reorganizing the information presented, incorporating key literature that is now missing, and by technical editing of both the text and glossary.

Section 5.3 of the Report should be reorganized to clarify the functional role of floodplains and riparian areas in maintaining the ecological integrity of streams and rivers. Much of the text in Section 5.3 is focused on riparian areas and the importance of headwater, streamside areas to in-stream structure and function. The SAB recommends that this material be moved from Section 5.3 to Chapter 4, which discusses physical, chemical, and biological connections of streams and riparian areas. In particular, the material in Sections 5.3.1 and 5.3.2, which focus on the physical and chemical influence of riparian areas on streams, is more appropriately located in Chapter 4. Chapter 4 already includes discussions of the role of riparian forests in regulating water temperature and providing inputs of large woody debris, but leaves the discussion of other functions, such as ability of these areas to act as nutrient sinks and transformers, to Chapter 5. Consolidating all of the literature review on riparian areas into Chapter 4 would help organize and clarify the text for the reader. This change would free Section 5.3 to~~to give more emphasis to~~ emphasize higher order structure and function related to the lateral dimensions of river systems and less emphasis to lower order riparian interactions.

Commented [MJ343]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [SF344]: (Fennessy)

Commented [MM345]: (Murphy)

Commented [MS346]: (Sullivan) I am not sure this is fully accurate as the Panel found that the actual literature on floodplains was pretty sparse, with a focus on non-floodplain riparian areas.

Commented [MM347]: (Murphy)

Commented [KK348]: (Kolm)

Commented [MM349]: (Murphy)

Commented [MJ350]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [LJ351]: (Johnson) Make this an overarching recommendation across all sections

Commented [JT352]: (Tank) This paragraph suggests that the section on the role of the riparian zone in fueling stream ecosystem processes be moved to Chapter 4. The omission of this topic was also mentioned in the section of the SAB Review of Charge Question 3(a), thus these sections should be cross referenced in the SAB Review so that EPA's reorganization is straightforward (reflecting a relocation rather than an omission).

Commented [SF353]: (Fennessy)

As written, Section 5.3 of the Report is 16 pages in length, with only about 6 pages that focus specifically on floodplain dynamics. As described below, this section should be strengthened considerably to more fully reflect the literature on the physical, chemical and biological linkages between floodplains and receiving waters (i.e., lateral exchange between floodplains and rivers followed by downstream transport). Some references are provided in Section 3.5.8 of this report.

The EPA should consider reorganizing the information on the different taxonomic groups (plants and phytoplankton, vertebrates, and invertebrates) that are described in Sections 5.3.3.1-5.3.3.3 of the Report to integrate the functional attributes of floodplains as habitats, rather than addressing each group one after the other, textbook style.

Recommendations

- Section 5.3 of the Report should be reorganized to clarify the functional role of floodplains and riparian areas on the ecological integrity of streams and rivers. Text in Section 5.3 that focuses on riparian areas and the role of headwater, streamside areas on in-stream structure and function should be moved to Chapter 4 of the Report.

- Section 5.3 of the Report should be strengthened considerably to more fully reflect the literature on the physical, chemical and biological linkages between floodplains and receiving waters (i.e., lateral exchange between floodplains and rivers followed by downstream transport).

- EPA should consider reorganizing the information on the different taxonomic groups (plants and phytoplankton, vertebrates, invertebrates) that are described in Sections 5.3.3.1-5.3.3.3 of the Report to integrate the functional attributes of floodplains as habitats, rather than addressing each group one after the other.

3.5.2. Terminology in Section 5.3 of the Report

As previously discussed, the terms "unidirectional" and "bidirectional" wetlands should be ~~revised to reflect the landscape position of the water body and/or wetland in question. Thus, it~~removed. It is recommended that bidirectional wetlands be called "waters and wetlands in riparian/floodplain settings." Unidirectional wetlands, as defined in the EPA Report are discussed in Sections 3.7 and 3.8 of this SAB report but would obviously not be part of a stream or its tributaries. This change in terminology is needed to acknowledge the ~~two-way~~multi-dimensional flux of water and materials between floodplains and riparian areas and ~~adjacent~~co-located rivers and streams. Consistent use of this term is important for clarity, as the inconsistent uses of "riparian/floodplain wetlands," "riparian areas," or "floodplains" in some sections of Chapter 5 is confusing ~~to readers. Likewise, the~~. The definitions of "Riparian Area," "Riparian Wetland," "Floodplain," "Floodwater," and "Floodplain Wetland" in the glossary of the Report should ~~align with the ways the terms are used in the text.~~be revised consistent with this definition.

Commented [MM354]: (Murphy)

Commented [MM355]: (Murphy)

The ~~treatment of floodplains in the Report presents challenges because (1) much of the literature on floodplains and riparian areas does not specify whether or not areas studied were wetlands, and (2) even when a floodplain is identified as a wetland, the literature seldom indicates if it was a jurisdictional wetland. Given this, the~~ SAB agrees ~~with~~ the ~~approach of the~~EPA authors ~~of the Report, which was to~~

takeon taking a broad view of floodplains that allowed a much, thus allowing a more representative cross section of the literature to be used. Moreover, the. The critical ecological and functional roles of floodplains and riparian areas must be acknowledged ininform the Report regardless of their regulatory status as wetlands as defined by (Cowardin et al. (1979). This approach is consistent with the rest of the Report, as wetlands. Wetlands discussed in the Report were not limited to those meeting the federal regulatory definition of wetland (33CFR 328.3(b); USACE 1987).. Including a statement that the text refers to "riparian areas, floodplains and waters and wetlands in riparian/floodplain settings" would clarify that the Report is referring to the landscape setting in its entirety, with its characteristic four-dimensions of connectivity (Ward 1989). However); however, the SAB also recommends that the authors clearly indicate these areas are covered in the report because of functional linkages, and not in an attempt to expand the definition of waters and wetlands under the jurisdiction of the Clean Water Act. Making this distinction will clarify the scope of the report and reinforce the goal of the report as a scientific, and not a policy, document. and not policy goals.

Recommendations

- The terms "unidirectional" and "bidirectional" wetlands should be revised to reflect the landscape position of the water body and/or wetland in question. Thus, it is recommended that bidirectional wetlands be called "waters and wetlands in riparian/floodplain settings."

- The definitions of "Riparian Area," "Riparian Wetland," "Floodplain," "Floodwater" and "Floodplain Wetland" in the glossary of the Report should align with the ways the terms are used in the text.

- The Report should discuss the functional role of floodplains and riparian areas regardless of their status as wetlands as defined by Cowardin et al. (1979). However, it should be made clear that this discussion does not imply an expansion of the definition of waters and wetlands under the jurisdiction of the Clean Water Act.

3.5.3. Spatial and Temporal Connectivity of Floodplain Environments to River Systems

Section 5.3 of the Report should include a new subsection that explicitly discusses how floodplain environments (including the terrestrial components thereof) are intimatelyfunctionally linked to river systems, both spatially and temporally, by means of the "flood pulse." The authors of the Report recognize the importance of spatial and temporal scales of connectivity between rivers streams and floodplains in the abstract, writing:

> *Connections between riparian/floodplain wetlands and other water bodies and streams or rivers can be permanent, can occur frequently (e.g., if the wetland is located within the mean high-water mark), or can occur infrequently (e.g., if the wetland occurs near the edge of the floodplain). Even riparian/floodplain wetlands that rarely flood can have important, long-lasting effects on streams and rivers. (p. 5-1, lines 12-16)*

However, Chapter 5 does not discuss this point. This is an important omission given that gradients in spatial and temporal connectivity between the stream and floodplain are primary determinants of physical and biological processes occurring within both the stream and the floodplain (Junk et al. 1989).

Commented [MM356]: **(Murphy)**

Commented [MJ357]: **(Josselyn)** I concur with the recommendations.

Commented [D358]: **(Patten)** and/or clarified relative to similarity or perhaps "combined"

Commented [M359]: **(Murphy)** Much of this discussion occurs earlier in the SAB report, in a slightly different, but with ultimately the same conclusion. We need to make sure that there is a stronger degree of consistency between the two discussions.

Commented [LJ360]: **(Johnson)** Does there need to be a short section acknowledging the inverse of flood, i.e., drought, and its implications wrt connectivity? Since human activities can exacerbate the effects of drought and there are regulatory implications to those activities I feel this should be addressed somewhere. This seems like a reasonable place to do that.

Commented [MM361]: **(Murphy)**

Commented [D362]: **(Patten)** and river to alluvial aquifer connectivity as the alluvial aquifer underlies the floodplain and is the water source for floodplain plants

The SAB recommends that a new spatial and temporal scale subsection in Chapter 5 emphasize that floodplain environments (including the terrestrial components thereof) are intimately linked to river systems through the "flood pulse." The "flood pulse concept" should be employed as the conceptual backbone of the subsection, stressing higher order structure and function (as noted above, this is in comparison to lower–order, headwater stream systems where the riparian area is an interface with the terrestrial environment, although recognizing that there exist gradients of floodplain development along the drainage network,). While the Report recognizes that the flood pulse concept is a fundamental paradigm in river ecology (p. 5–6, line 5; page 6–4, lines 1-2), its hydrologic character in either spatial or temporal dimensions remains undeveloped and separate from the conceptualization of how "riparian/floodplain wetlands" operate. The Report does recognize the extension of the flood pulse concept to include "flow pulses" (Tockner et al. 2000) but does little to emphasize how floodplains (and the wetlands within them) are differentially connected to river systems through storm–related changes in flow, seasonal variation in water abundance and river discharge, and longer–term changes related to climate shifts and precipitation regimes. The term "flood pulse" is used only 9 times in the body of the entire Report. Most of the references to "flood pulse" in the Report relate to attenuation of flooding in main channel (p. 5–6, lines 5, 29; Table 5–3, page 5–38), or the influence of the flood pulse on biological entities (e.g., page 5–20, lines 16, 22, 29).

There should also be increased emphasis in the Report on the temporal aspects of floodplain systems as guided by the short duration high intensity "flood pulse concept" for surface waters and long duration low intensity lateral discharge for groundwater. The temporal progression of the flood pulse should be discussed, including descriptions of the influence of the flood pulse on residence time of surface water, seasonal exchanges with groundwater, chemical and biological linkages, and ecosystem processes. For example, the effects of a high-intensity flood event of low frequency and duration on downstream waters will be mostly physical, including water storage, peak flow attenuation, and sediment and wood transport and/or deposition. This is a low-frequency, high-intensity flood that occurs on a decadal or centennial return interval. The spatial scale of this type of flood event tends to be extensive, dictated largely by topography, and covering all available habitats. At the other end of the spectrum, the effects of high-frequency low-intensity forms of connectivity (such as hyporheic groundwater flow) may be more biological or biogeochemical, including nutrient and contaminant transformation and organic matter accumulation. The spatial scale of this type of connectivity depends on whether groundwater discharge in the floodplain is discrete (e.g., a spring) or diffuse, and whether it travels through the floodplain as channelized flow or in the hyporheic zone.

One very practical reason for including an explicit discussion of the scales of connectivity in the Report is that some floodplains that are inundated at a low frequency may not exhibit wetland soils, vegetation, or hydrology required to meet the federal regulatory (33 CFR 328.3) or the Cowardin et al. (1979) definition of wetland. However, even this occasional connectivity to rivers and streams plays an important role in river hydrology and water quality. Where streams are disconnected from their floodplains, low-frequency, high-intensity floods can have major negative impacts on downstream ecosystems and human communities. Thus, a gradient of temporal connectivity is also critical to establish.

Placing the wetlands of "riparian/floodplain" environments into the context of the "river corridor" requires developing a perspective of linkage and expansion. The authors of the Report need to clearly articulate the bidirectional nature of fluxes and connections back to the river channel, focusing on the fluxes of water, materials, and biota and emphasizing how exchange flows respond to the temporal

Commented [D363]: **(Patten)** plus four dimensional components of system (including groundwater...alluvial aquifer). Water does not only go on the surface via flood pulse.

Commented [M364]: **(Murphy)** Mild departure in opinion here. The flood pulse concept, as I understand it, has progressed beyond the original article. One of the things that I am most familiar with is the work of Julie Stromburg at ASU and Waite Osterkamp at the USGS who individual show how fluvial structure is dynamic altering the response of the community to each geomorphic disturbance where that be tied to regular annual or bankflow flooding or catastrophic events. I would prefer we just stick to the need to more fundamentally use multi-, or four-, dimensional structure and magnitude, frequency and duration in the EPA report; however, we should clearly cite the flood pulse concept as reflective of the continuing understanding of disturbance ecology in fluvial systems and encourage EPA to use its ideas.

Commented [MS365]: **(Sullivan)**

Commented [D366]: **(Patten)** this point gets lost in the following discussion which emphasizes flood pulse

Commented [MJ367]: **(Josselyn)** While I agree with this statement that the report should discuss degrees of connectivity, it needs to be clearly related to downstream water quality and not just water quantity or changes in hydroperiods. I disagree that the Report should go into details on flood management. I recommend deleting this paragraph.

Commented [LJ368]: **(Johnson)** Should this articulate the reason / mechanism, i.e., reduction in flood storage exacerbating the peak and timing of the hydrography?

Commented [MS369]: **(Sullivan)**

progression of the flood pulse and move back to the channel. This will reflect flowpaths described in the conceptual model shown described in Section 3.2 of this review. As such, Section 5.3 of the Report should~~needs to~~ stress the effects of floodplains not only on river flows, but also on chemistry, sediments, and biota of downstream waters. The SAB provides a number of specific recommendations in this regard. Flood-forecasting methods could~~should~~ be used as a means to quantify the strength of connectivity (spatial and temporal) between floodplains and rivers. Hydrological methods in flood frequency – floodplain inundation provide estimates of water residence time (or hydroperiod) on floodplains, with implications for fluxes of biota and biogeochemical processing, for example, of nitrogen (N) and phosphorus (P). The results are measures of vertical and lateral connectivity. Analyses of this kind require that recurrence intervals be explicitly defined, for example making estimates over a reasonable range of overbank flows (2 years out of 3, to 10-yr and 100-yr events), to establish variability in the time scales of connectivity. Such analyses would focus much needed attention on magnitude-frequency relationships referred to in sections X,Y,Z.
.

The EPA should consider incorporating into the Report examples of floodplain classification systems (e.g., References needed here) that would address floodplain geomorphological and functional diversity and place emphasis on the continuum of floodplains along stream networks. This would lead to a better understanding of factors that shape the degree of connectivity between floodplains and receiving waters by describing floodplain/channel geomorphology and the duration of flooding or saturation. The SAB also recommends addressing channel migration zones, which describe the movement of channels within floodplains over time as a result of large floods, and explaining the variable nature of connectivity (in space and time) of floodplains and the waters/wetlands that they contain.

The Report should emphasize the importance of ~~hydrological~~ floodplain connections and processes such as sediment movement, erosion and deposition that operate through downstream, lateral, vertical and temporal dimensions. Additional literature should be reviewed and cited in the Report to demonstrate that lateral connections create a diversity of lotic, semi-lotic and lentic habitats~~,~~ within the riparian zone, supporting a wide array of ~~species~~ taxa (e.g., fish, amphibians, birds, mammals) and high levels of diversity. More emphasis is needed in Section 5.3 of the Report on these biological exchanges~~.~~ within the floodplain. The SAB has provided some references (cited below) that address the role of wetlands and off-channel waters on floodplains as fish nurseries that act to populate downstream fisheries. These references include studies describing fish species that spawn and rear in backwaters and floodplain wetlands that~~, which~~ flood ~~in the winter and early spring wet season~~during high-water seasons, then dry down ~~in the summer.~~ as flow decreases. As previously mentioned, these habitats are particularly important for fish larvae. Similarly, some endangered fishes have been shown to use backwaters extensively for spawning and rearing (e.g., Modde et al. 2001; 2005; Bestgen et al. 2007). The report would be further strengthened by discussing the importance in detail of these floodplain habitats ~~for species that are economically important~~ and~~/or listed as threatened or endangered by federal and state agencies.~~ their multi-dimensional connectivity.

The SAB also finds that it would be instructive to broaden the range of examples used in the Report and make it more representative of the U.S. as a whole. For instance, the EPA could incorporate studies on peatlands in floodplain settings that have bidirectional flows, as in northern tier states and Alaska.

Recommendations

Commented [D370]: (Patten) groundwater moves in and out, just as floods move back and forth.

Commented [SF371]: (Fennessy)

Commented [SF372]: (Fennessy)

Commented [LJ373]: (Johnson) Good to link these recommendations that cross chapters and sections

Commented [LJ374]: Good to link these recommendations that cross chapters and sections

Commented [LJ375]: (Johnson)

Commented [MM376]: (Murphy)

Commented [MM377]: (Murphy)

Commented [MS378]: (Sullivan)

Commented [MM379]: (Murphy)

Commented [M380]: (Murphy) Not in all regions.

Commented [MM381]: (Murphy)

Commented [MM382]: (Murphy)

Commented [LJ383]: (Johnson) Overarching recommendation

Commented [D384]: (Patten) can we give more than one example

Commented [MJ385]: (Josselyn) I do concur with the recommendations, especially those that relate to a better understanding of how the scientific literature can be used to establish differences in connectivity on temporal and spatial scales and that the basis for the floodplain classification be discussed in the Report.

- Section 5.3 of the Report should contain a new subsection that explicitly discusses how floodplain environments (including the terrestrial components thereof) are intimately linked to river systems, both spatially and temporally, by means of the "flood pulse." The "flood pulse concept" should be employed as the conceptual backbone of the new subsection, stressing higher order structure and function (in comparison to lower–order, headwater stream systems where the riparian area is an interface with the terrestrial environment).

- Section 5.3 of the Report should emphasize the importance of the temporal dimension of floodplain systems as guided by the short duration high intensity "'flood pulse concept" for surface waters and long duration low intensity lateral discharge for groundwater.

Commented [D386]: (Patten) this point seems to not be emphasized with the extensive discussion of flood pulse lateral connectivity above

- Section 5.3 of the Report should emphasize the effects of floodplains not only on river flows, but also on chemistry, sediments, and biota of downstream waters.

- Flood-forecasting methods should be used as a means to quantify the strength of connectivity (spatial and temporal) between floodplains and rivers.

- The EPA should consider incorporating into the Report examples of floodplain classification systems to address the geomorphological and functional diversity of floodplains, and to place emphasis on the continuum of floodplains along stream networks.

- The Report should include a discussion of channel migration zones, which describe the movement of channels within floodplains over time as a result of large floods, and demonstrate the variable nature of connectivity (in space and time) of floodplains and the waters/wetlands that they contain.

- The Report should stress the importance of hydrological connections and processes such as sediment movement, erosion and deposition that operate through downstream as well as lateral, vertical and temporal dimensions.

- Additional literature should be reviewed and cited in the Report to demonstrate that lateral connections create a diversity of lotic, semi-lotic and lentic habitats, supporting a wide array of ~~species~~taxa (e.g., fish, amphibians, birds, mammals) and high levels of diversity. More emphasis is needed in Section 5.3 of the Report on these biological exchanges.

Commented [MS387]: (Sullivan)

- The range of examples used in the Report should be broadened to make it more representative of the U.S. as a whole. For instance, the EPA could incorporate studies on peatlands in floodplain settings that have bidirectional flows, as in northern tier states and Alaska.

3.5.4. Export versus Exchange

Floodplains and waters and wetlands in floodplain settings are shaped by repeated inundation, saturation, erosion and deposition of sediment, and movement of biota. Water and materials flow laterally between floodplains and rivers (i.e., receiving waters), moving onto the floodplain in periods of high flows and back to the channel as floods recede. As mentioned above, the Report text as written does not clearly articulate the ~~bidirectional~~multi-dimensional nature of ~~fluxes/connections~~ connectivity between the floodplain and channel. The SAB recommends strengthening the focus of the Report on the

Commented [MM388]: (Murphy)

fluxes of water, materials and biota to emphasize how exchange flows respond to the temporal progression of the flood pulse.

Recommendation

- There should be a stronger focus in the Report on the bidirectional fluxes of water, materials and biota to emphasize how exchange flows respond to the temporal progression of the flood pulse.

3.5.5. Biogeochemical Linkages

Wetlands and floodplains serve as sinks, sources and transformers of nutrients and other chemical contaminants, and have a significant impact on downstream water quality and ecosystem productivity. The primary driver of wetland processes is ecosystem biogeochemistry, which involves the exchange or flux of materials between living and non-living components. These fluxes involve interaction of complex physical, chemical, and biological processes in various components of the wetland ecosystem. Biota (plants, microbes, and fauna) can be considered as exchange pools, which are small in size and undergo rapid turnover and cycling. Abiotic components of wetlands (e.g., soil), which are large in size, undergo slow turnover and provide long-term storage similar to a reservoir. The amount of a given constituent in these pools depends on its residence time. These issues are important to acknowledge in the Report. The SAB recommends that the authors of the Report provide a more recent and diverse assessment of the biogeochemical implications of exchange flows. This can be accomplished by enhancing the review of the literature on the role of wetlands and floodplains as sources, sinks, and transformers of materials including: nutrients, metals, organic contaminants, and sediments. The Report sections on nitrogen processing (denitrification), phosphorus cycling, and sediments (including legacy sediments and associated chemicals) could be strengthened with an expansion of the literature reviewed. The review on nitrogen processes in Section 5.3.2.2 of the Report is of particular concern due to its very heavy reliance on a single paper by Vidon et al. (2010), cited fully 20 times in that section, on the fate and fluxes of nitrogen in riparian areas. There is an extensive literature on this subject and while the Report correctly characterizes nitrogen transformations in a general sense, there are many key references that are not included. For example, Section 5.3.2.2 of the Report should be updated to provide a more recent and diverse assessment of biogeochemical implications of "hot-spots and hot-moments" in nitrogen fluxes that are associated with hydrologic exchanges between surface and subsurface waters (McClain et al. 2003); see also extensive work by Groffman et al. (2003). The SAB also recommends that, in general, the literature findings in the Report be reported more quantitatively and not by simple qualitative statements indicating, for example, that nitrogen levels increased or decreased. In this specific example the Report should indicate the percent concentration change. The SAB notes that, depending on hydrologic connectivity, riparian/floodplain soils exhibit a range of redox conditions, which then regulate biogeochemical cycling of key nutrients, metals, and organic compounds.

The Report should indicate that changing climatic conditions may stimulate or alter rates, fluxes and storage pools of key elements (carbon, nitrogen phosphorus, and sulfur) involved in biogeochemical processes and services provided by wetlands. For example, accelerated decomposition of organic matter can potentially increase nutrient generation, which may lead to increased nutrient/contaminant loading to adjacent water bodies. Important inorganic elements in wetlands are mobile and thus their concentrations may increase upon flooding and drainage cycles, water withdrawals, sea level rise, and increases in temperature. The bioavailability of many inorganic elements required for key biological processes (e.g., plant growth and decomposition) will respond to these changing conditions. Drainage

Commented [MJ389]: (Josselyn) I concur with the recommendation.

Commented [MS390]: (Sullivan)

Commented [MJ391]: (Josselyn) This section is well written and points out the over reliance on a single paper for much of the findings. I concur with the recommendations.

Commented [LJ392]: (Johnson) Do microbes need to be mentioned here as well?

Commented [LJ393]: (Johnson) Overarching recommendation

also increases enzyme and microbial activities, which facilitates oxidation of organic matter, leading to subsidence and loss of organic soils. Many studies have shown that oxidation of organic matter in wetlands is dependent on water-table depth, temperature, nutrient loading, vegetation communities and release of nutrients. Bidirectional exchange of particulate organic matter (POM) and dissolved organic matter (DOM) in riparian areas and floodplains can be an important source of POM and DOM to streams and rivers. Further treatment of the residence time of water should also be considered. Water residence time is a critical concept that can have significant biological impacts, which can be particularly relevant to downstream waters. Powers et al. (2012) point out that aquatic ecosystem components that have relatively high nutrient processing rates may not contribute substantially to total ecosystem retention unless enabled by hydrological connections.

Recommendations

- The Report should provide a more recent and diverse assessment of the biogeochemical implications of exchange flows. This can be accomplished by enhancing the review of the literature on the role of wetlands and floodplains as sources, sinks, and transformers of materials including: nutrients, metals, organic contaminants, and sediments (additional references are provided in section 3.5.8 of this SAB report).

- The Report sections on nitrogen processing (denitrification), phosphorus cycling, and sediments (including legacy sediments and associated chemicals) should be strengthened by expanding the literature reviewed. In particular, Section 5.3.2.2 of the Report should be updated to provide a more recent and diverse assessment of biogeochemical implications of "hot-spots and hot-moments" in nitrogen fluxes that are associated with hydrologic exchanges between surface and subsurface waters (Groffman et al. 2003; McClain et al. 2003).

- Literature findings in the Report be reported more quantitatively and not by simple qualitative statements, for example, that nitrogen levels increased or decreased.

- The Report should further discuss how changing climatic conditions may stimulate or alter rates, fluxes and storage pools of key elements (carbon, nitrogen phosphorus, and sulfur) involved in biogeochemical processes and services provided by wetlands (additional references are provided in section 3.5.8 of this SAB report).

- The EPA should consider including in the Report further discussion of the residence time of water. Water residence time is a critical concept that can have significant biological impacts, which can be particularly relevant to downstream waters (additional references are provided in section 3.5.8 of this SAB report).

3.5.6. Case Study on Forested Wetlands

The SAB finds that the report would benefit from more discussion of forested wetlands, including bottomland hardwoods, given their ecological importance, rate of loss, and unique attributes. These wetlands represent a significant portion of remaining U.S. wetlands. A box case study could address this gap, and include the role of bottomland forests on river biogeochemistry and flood storage.

Recommendation

Commented [LJ394]: **(Johnson)** Here is another link to drought.

Commented [JT395]: **(Tank)** The bullet point emphasizing the importance of water residence time seems to be an afterthought; it is currently placed last, in a long list of bullet points. It may serve to move this point to the front of the bulleted list, as it influences many of the important processes that have been suggested here, and that have been highlighted for expansion in the text of the Report.

Commented [MJ396]: **(Josselyn)** I concur with this recommendation assuming that the approach used will be consistent with the other case studies.

- A case study of the role of forested wetlands (including bottomland hardwoods) in river biogeochemistry and flood storage should be included in the Report.

Commented [JT397]: (Tank) It is unclear from the bullet as written that this is a case study "box" that is being suggested, rather than a new "chapter-level" case study.

3.5.7. Human Impacts to Floodplains and Aggregate Effects

The effect of human impacts to waters and wetlands in riparian/floodplain settings on connectivity is an important issue that should be addressed in the Report. An example of such an impact is channel incision or levee construction that breaks the link between riparian wetlands/floodplains with downstream waters. Alterations that decrease the connectivity of floodplains and waters and wetlands in riparian/floodplain environments provide some of the clearest demonstrations of the functional role of these areas with respect to downstream waters (for example, through degraded water quality). A key approach to this analysis is to provide examples of the aggregate effects of floodplain impacts on downstream waters in terms of flooding, biodiversity, and materials flux. Barkesdale et al. (2013) provide information on the effect of watershed land conversion and associated runoff on the hydrology and carbon cycling of headwater wetlands in coastal Alabama. The water quality benefits of riparian areas and floodplains should also be highlighted in the Report by explicitly pointing out that their destruction exacerbates nutrient runoff from agricultural lands by reducing or eliminating nutrient uptake, dentrification, and sedimentation of adsorbed phosphorus.

Commented [LK398]: (Kalin)

Recommendations

Commented [MJ399]: (Josselyn) I concur with the recommendations. Such alterations can become part of the normal condition upon which regulatory agencies must make decisions on jurisdiction. Such alterations can sever connectivity in many ways and should be explained in more detail such that the proposed rulemaking can consider them, especially in urbanized situations.

- The Report should address the effects of human impacts to waters and wetlands in riparian/floodplain settings on connectivity.

- The water quality benefits of riparian areas and floodplains should be highlighted in the Report by explicitly pointing out that their destruction exacerbates nutrient runoff from agricultural lands by reducing or eliminating nutrient uptake, dentrification, and sedimentation of adsorbed phosphorus.

3.5.8. Recommended References

Commented [JT400]: (Tank) Recommended References" is a separate section for the SAB Review of this Charge Question. In contrast, suggested references are treated differently in other sections. The SAB Review might want to consider standardizing the location of these additional references- I prefer these to be at the end of each topic area instead of all at once.

The SAB recommends that the EPA authors should consider ~~adding~~reviewing the following selected references as support to the Report.

Commented [MM401]: (Murphy)

- References to studies emphasizing how the hydrologic phenomenon of the flood pulse links rivers to the floodplain (and consequently to wetlands within them): Alford and Walker (2013); Anderson and Lockaby (2012); Benke et al. (2000); Bunn et al. (2006); Ellis et al. (2001); Galat et al. (1998); Granado and Henry (2014); Heiler et al. (1995); Henson et al. (2007); Hudson et al. (2012); Hudson et al. (2013); Magana (2013); Nanson and Croke (1992); Opperman et al. (2010); Power et al. (1995a,b); Powers et al. (2012); Rooney et al. (2013); Schramm and Eggleton (2006); Sullivan and Rodewald 2012; Sullivan and Watzin (2009); Thorp et al. (2006); Tockner et al. (2000); Toth and van der Valk (2012); and Valett et al. (2005).

- References on Biogeochemistry: Aitkenhead-Peterson, et al. (2003); Fowler (2004); Bridgham et al. (2001); Bridgham et al. (2006); Buresh et al. (2008); Fennessy and Cronk (1997); Freeman et al. (20004a); Freeman et al. (2004b); Hefting et al.(2004); McClean et al. (2003); Osborne (2005);

Qualls and Richardson. (2003); Reddy et al. (1999); Reddy et al. (2005); Reddy et al. (2011); Strack et al. (2008); Wetzel (1990); and Wetzel (2002).

- References on human impacts: Dudley and Platania (2007); and Verhoeven et al. (2006).

- References on fauna: Brooks and Brinson (2013); Baxter et al. (2005); Bestgen et al. (2006); Bestgen et al. (2007); Bottom et al. (2005); Fausch (2010); Flecker et al. (2010); Gresswell (2011); Koel et al. (2005); McIntyre et al. (2007); Mion et al. (1998); Modde et al. (2001); Modde et al. (2005); Schick and Lindley (2007); Spinola et al. (2008); and Zelasko et al. (2010).

3.6. Review of the Findings and Conclusions Concerning Waters and Wetlands in Riparian/Floodplain Settings

Charge Question 4(b). Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

3.6.1. Scientific Support for the Findings and Conclusions Concerning Waters and Wetlands in Riparian/Floodplain Settings

The SAB is in agreement that there is strong scientific support for the conclusion that riparian and floodplain water bodies and wetlands are highly connected to downstream waters through multiple pathways, including hydrological, chemical, and biological connectivity. However, as further discussed below, the SAB recommends that additional literature be included in the Report to bolster these findings, particularly as related to chemical connectivity. In addition, the SAB notes that the key findings and conclusions presented in Section 1.4.2 of the executive summary of the Report should be directly related to the information presented in Section 5.3 on Riparian and Floodplain Wetlands. The discussion of findings and conclusions in these two sections should be parallel. Any conclusions presented in Section 1.4.2 of the executive summary should also align with conclusions presented in Sections 5.5, the wetlands synthesis and implications discussion, and 6.1, the discussion of major conclusions.

Currently, many of the conclusions in the Report are drawn from literature related to riparian zones that are adjacent to water bodies other than floodplains that are periodically inundated (i.e., non-floodplain riparian zones). This weakens the potential opportunity to present direct evidence of connectivity (or lack thereof) between waters and wetlands in riparian/floodplain settings and receiving systems. The SAB views this discrepancy as highly problematic. In addition, there appears to be a lack of clarity in distinguishing the science (and cited literature) related to floodplain areas that are not wetlands from the science related to floodplains that either contain wetlands (floodplain wetlands) or are inundated with sufficient frequency to be classified as wetlands. The SAB recommends presenting a broad discussion of floodplain systems in Section 5.3 (to replace the current riparian focus), but the distinction between floodplain areas that are not wetlands and floodplain areas that contain or are wetlands needs to be clear relative to the implications for connectivity, and should be highlighted and carried through the text and conclusions. The discussion of floodplains that are neither wetlands nor inundated frequently enough to be wetlands may risk criticism because it appears to either expand the definition of a river or

Commented [M402]: (Murphy) See my previous comments. Need to patrol consistency here.

Commented [MJ403]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [SF404]: (Fennessy) This is a good suggestion for all of the Conclusions sections

downstream waters (not now included in the definition of rivers in the glossary) or to bring into the Report another landform unrelated to rivers per se (active channel) and wetlands or other water bodies.

Recommendations

- There is strong scientific support for the conclusion that riparian and floodplain water bodies and wetlands are highly connected to receiving waters through multiple pathways, including hydrological, chemical, and biological connectivity. However, additional literature should be included in the Report to bolster these findings, particularly as related to chemical connectivity.

- Key findings and conclusions presented in Section 1.4.2 of the executive summary of the Report should to be directly related to the information presented in Section 5.3 on Riparian and Floodplain Wetlands.

- Conclusions presented in Section 1.4.2 of the executive summary should align with conclusions presented in Sections 5.5, the wetlands synthesis and implications discussion, and 6.1, the discussion of major conclusions.

- A broad discussion of floodplain systems should replace the current riparian focus and be included in Section 5.3 of the Report, but the distinction between floodplain areas that are not wetlands and floodplains that contain or can be classified as wetlands needs to be clear relative to the implications for connectivity, and should be highlighted and carried through the text and conclusions.

3.6.2. Additional Recommendations Concerning the Findings and Conclusions Regarding Waters and Wetlands in Riparian/Floodplain Settings

The SAB recommends that the EPA address the following issues in the discussion of waters and wetlands in riparian /floodplain settings.

Inconsistent Terminology

As previously mentioned, the Report language referring to riparian and floodplain wetlands should remain consistent both within the key findings and conclusions sections as well as throughout Section 5.3. The terms "riparian areas," "riparian and floodplain areas," and "riparian/floodplain waters" are used inconsistently in Tables 5.1 and 5.3. The SAB finds the use of the terms "riparian" and "floodplain" areas to be particularly problematic, as these terms extend beyond water bodies. The terms "riparian" or "riparian areas" should be used sparingly unless they refer directly to riparian wetlands or floodplains that are classified as wetlands by frequency of inundation because it leaves the appearance of relying on non-wetland riparian areas to support the report, thereby extending the report beyond its key objectives. The SAB notes that the glossary definitions in the Report distinguish between "riparian areas" and "riparian wetlands" as well as among "floodplain," "floodwater," and "floodplain wetland." "Upland" is also defined in the glossary as: *(1) Higher elevation lands surrounding streams and their floodplains. (2) Within the wetland literature, specifically refers to any area that is not a water body and does not meet the Cowardin et al. (1979) three-attribute wetland definition.* As previously discussed, the SAB recommends that "bidirectional" wetlands be called "waters and wetlands in riparian/floodplain settings." The terminology used in the key findings and conclusions of the Report must align with the glossary definitions and the conceptual framework.

Commented [SF405]: (Fennessy) We should be sure that the points made here match what is stated in 3.5.3 of this report. For instance on page 36, lines 14-20 we say "some floodplains that are inundated at a low frequency may not exhibit wetland soils, vegetation, or hydrology required to meet the federal regulatory (33 CFR 328.3) or the Cowardin et al. (1979) definition of wetland. However, even this occasional connectivity to rivers and streams plays an important role in river hydrology and water quality." The caution made in this paragraph is a good one; we want to be consistent, and mirror what is said in our section 3.2.2 about the broader definition of wetlands that is used in the Report (i.e., the 1-parameter versus the 3-parameter regulatory definition). As stated above, we are taking "the large set of waters and wetlands" regardless of the current regulatory system.

Commented [LB406]: (Benda) This highlights an apparent inconsistency in the SAB review document. The SAB needs to clarify whether this statement represents our consensus because it appears to be inconsistent with the 3.3.8 (Expanding the Discussion of the Effects of Streamside Vegetation on Stream Ecosystems) where it recommends that the EPA Draft Report include a discussion of the beneficial effects of stream side vegetation on streams and rivers (litterfall, shade, large wood); these effects can be unrelated to wetlands or frequently inundated floodplains (thus defined as wetlands), and can originate from non floodplain areas (terraces and toe-slopes of hillsides).
This issue also shows up on Pg. 43 (3.6.2, lines 8-12) where it states that "the terms "riparian" or "riparian areas" should be used sparingly unless they refer directly to riparian wetlands or floodplains classified as wetlands….because it leaves the appearance of relying on non-wetland riparian areas to support the report, thereby extending the report beyond its key objectives"
If there is consensus to include the riparian effects (3.3.8), then the statements made under 3.6.1 and 3.6.2 should be omitted or revised. Perhaps EPA can advise on this.

Commented [LJ407]: (Johnson) Many of the items below are not "additional" they are repeated in the above sections

Commented [MJ408]: (Jossleyn) See my comments on this section in the general comments on the draft report.

Commented [SF409]: (Fennessy) I have the same comment here as above on page 42; we should be sure we are consistent on these points. There is also the complication that most wetlands studies do not specify whether or not the sites are wetlands by either the 1- or 3-parameter definition.

Commented [D410]: (Patten) don't we ask or shouldn't we ask for some consistency among these terms or at least some clarity of their differences.

Temporal Component

As previously mentioned, the key findings and conclusions in the Report should recognize the temporal dimension of waters and wetlands in riparian/floodplain settings relative to downstream connectivity, consistent with the four-dimensional nature of the conceptual framework set forth in Chapter 2; water residence times and the transient nature of floodplains should be key points. This temporal perspective, combined with an emphasis on developing (and illustrating) ~~a~~the strength of connectivity, could be done using the well-developed science of flood forecasting (probability) as a function of vertical and lateral connectivity. Incorporating discussion of flood frequency-floodplain inundation science into the Report might prove to be the best way to highlight how hydrologists estimate the degree of connectivity. As previously mentioned, discussion of "channel migration zones" would further address the lateral connectivity (example reference needed) of rivers to their valley floors (not necessarily floodplains but including non-floodplain valley floors). In one year a floodplain can exist on one side of the channel and the next year, following a large flood, the active channel may have migrated 100 meters to the opposite ~~size~~side, stranding the former floodplain and creating new floodplains on that side. Thus floodplains, including wetlands, are temporally variable and transient, and connectivity could include what has been referred to as the "channel migration zone." Some states have promulgated regulations about how to define and protect (regulate development) channel migration zones that are non-floodplain portions of the valley floor. Overall, the EPA's conclusions concerning connectivity of waters and wetlands in riparian/floodplain settings should reflect the main message of a new spatial and temporal subsection in Section 5.3, as recommended in the SAB response to Charge Question 4(a).

Further Quantification of Key Conclusions

The key conclusions in the Report should be more empirically and/or more specifically described. Whenever possible, the degree of and/or strength of evidence for connectivity should be quantified (e.g., of X studies, X% support conclusion of connectivity).

Quantification of Groundwater Linkages

The role of groundwater movement and storage, including the effects of "flood pulses" and the differences between "slope wetlands and riverine wetlands" given HGM-type classifications, and the role of chemical/contaminant movement and storage related to groundwater systems in floodplains has been documented (characterized) and quantified (flow and transport modeling). Quantification floodplain systems has been conducted in both steady-state and transient analysis to simulate the temporal changes. This may require additional literature review.

Chemical Linkages

The role of waters and wetlands in riparian/floodplain settings in storing and transforming chemical constituents should be expanded under Key Finding (d) in Section 1.4.2 of the Report. This may require additional literature review (in Section 5.3) in order to refer to literature on riparian and floodplain wetlands and water bodies rather than rely on riparian and upland examples. Changes to nitrate and dissolved organic carbon (DOC), as well as sediment storage, should be easily documented. There is ample literature on the water purification function of wetlands, and this is the rationale for constructed wetlands.

Commented [LB411]: (Benda) See my comments on this section in the general comments on the report.

Commented [LJ412]: (Johnson)

Commented [JT413]: (Tank) The discussion of temporal variation and the transient nature of some floodplains seems out of place here, and more relevant for the prior Charge Question section on the literature review. Alternatively, it could be highlighted in both Charge Question 4(a) and 4(b). I agree that this is a very important point, including introduction of term "channel migration zone", but it was not emphasized this clearly in the previous section, and thus seems "new" here.

Commented [GA414]: (Ali) A similar recommendation should be made for the "unidirectional wetlands" discussion in Section 5.4 of the EPA Report.

Commented [KK415]: (Kolm) Additional text.

Commented [JT416]: (Tank) Only DOC, nitrate, and sediments are identified here as potential examples. Expansion to "nutrients (both N and P) and sediments" would improve the suggested changes. Additionally, changing the term "water purification" perhaps to "improved water quality" would be more consistent with language previously used in SAB Review document.

Commented [LJ417]: (Johnson) There is an opportunity here to link this recommendation specifically to EPA mandates to regulate and manage for chemical contaminants.

Biological Linkages Including Food Webs

The role of biological connectivity between waters and wetlands in riparian/floodplain settings and receiving systems should be further highlighted in the key findings and conclusions. In particular, the SAB encourages the EPA to highlight the point that waters and wetlands in riparian/floodplain settings and receiving systems are intimately linked through biological connections (including integrated wetland-river food webs) across a range of spatial and temporal scales. In this regard, the report should explicitly discuss linkages to downstream waters. For example: "Riparian wetlands can provide critical nursery habitat for fish, *which then disperse into downstream waters, becoming part of river food webs and serving as a biological vector of nutrients.*" There also may be an opportunity to mention the importance of waters and wetlands in riparian/floodplain settings to species that are economically important as well as those species that are state and/or federally listed as endangered, but this would have to be first developed in the body of the Report.

Export versus Exchange

As previously discussed, an "exchange" versus "export" framework (i.e., reciprocal exchanges between waters and wetlands in riparian/floodplain settings and receiving waters) should be used in the Report. In this way, the EPA can clearly indicate that bidirectional biological, chemical, and hydrological transfers characterize the connections between the two systems.

Case Studies

The SAB finds that the case studies in the Report are useful. However, the findings from the case studies should be more explicitly linked to the overall conclusions in Section 1.4 of the Report.

Human Impacts

In some cases, human alteration of connectivity provides the clearest demonstration of how the function of waters and wetlands in riparian/floodplain settings is linked to adjacent waters. Thus, the conclusions in the Report could be strengthened by explicitly mentioning how human activities (impairment as well as restoration) alter connectivity of waters and wetlands in riparian/floodplain settings with downstream waters. Mention should be made of alterations that both increase connectivity, such as ditches, and decrease connectivity, such as levees. Again, using the flood frequency-lateral connectivity argument, this might represent a strong opportunity to illustrate how diking has clearly diminished connectivity both in individual river segments and in aggregate. Many floodplains along long stretches of rivers, if not entire rivers, may be affected by diking.

Aggregate/Cumulative Effects

The importance of considering waters and wetlands in riparian/floodplain settings in the aggregate should be underscored in the key findings and conclusions of the Report. For example, these sections could briefly illustrate how floodplain storage in the aggregate (e.g., floodplains in dozens to hundreds of individual channel reaches) yields many ecological services, including flood attenuation.

Recommendations

Commented [D418]: (Patten) have we not suggested earlier that case studies be presented in a "side box" approach and if not, we should.

Commented [M419]: (Murphy) I actually find the Case Studies much less than useful. They give the report an authority that it does not have. They actually are not real case studies, just examples of the kinds of aquatic ecosystems that EPA expects to encounter. However, there is no analytical couple between (1) the kinds of generalizations about connectivity made in the report, (2) the way in which the Case Studies demonstrate the major conclusions, or (3) how the conclusion might be used to better protect the ecosystems described in the Case Studies. Thus the Case Studies have little purpose and should be either scrapped or better integrated into the report.

Commented [LJ420]: (Johnson) Or water extraction activities that reduce water table

Commented [JT421]: (Tank) Diking is the only example used here, but in addition, routine dredging/channelization, especially in agricultural landscapes, severely impair (or eliminate) floodplain function and should be noted as such.

Commented [M422]: (Murphy) If the kind of gradational connectivity described in the Letter to the EPA Administrator was used in the EPA Report, cumulative effects would be easy to evaluate as a probability tree, with conditional effects calculated at each stream junction. This would allow regulators to focus on the locations of maximum harm in the watershed. The alternative and current practice would be to apply remedies equally throughout the watershed . . . a waste of time and money.

- Report language referring to riparian and floodplain wetlands should remain consistent both within the key findings and conclusions sections as well as throughout Section 5.3.

- The terms "riparian" or "riparian areas" should be used sparingly unless they refer directly to riparian wetlands or floodplains that are classified as wetlands by frequency of inundation because it leaves the appearance of relying on non-wetland riparian areas to support the report, thereby extending the report beyond its key objectives.

- The terminology used in the key findings and conclusions of the Report must align with the glossary definitions and the conceptual framework.

- The key findings and conclusions in the Report should recognize the temporal dimension of waters and wetlands in riparian/floodplain settings relative to downstream connectivity, consistent with the four-dimensional nature of the conceptual framework set forth in Chapter 2; water residence times and the transient nature of floodplains should be key points. The well-developed science of flood forecasting (probability) as a function of vertical and lateral connectivity may be particularly useful in developing this temporal perspective

- The key conclusions in the Report should be more empirically and/or more specifically described. Wherever possible, the degree of and evidence for connectivity should be quantified (e.g., of X studies, X% support conclusion of connectivity).

- The findings from the case studies in the Report should be explicitly linked to the overall conclusions.

- The role of waters and wetlands in riparian/floodplain settings in storing and transforming chemical constituents should be expanded under Key Finding d in Section 1.4.2 of the Report.

- The role of biological connectivity between waters and wetlands in riparian/floodplain settings and downstream waters should be further highlighted in the key findings and conclusions.

- The conclusions in the Report should explicitly discuss how human activities (impairment as well as restoration) alter connectivity of waters and wetlands in riparian/floodplain settings with downstream waters.

- The importance of considering waters and wetlands in riparian/floodplain settings in the aggregate should be underscored in the key findings and conclusions of the Report.

3.6.3. Alternative Wording for Findings and Conclusions

The SAB recommends the technical and editorial corrections provided in Appendix B to clarify the findings and conclusions in Section 1.4.2 of the Report.

Commented [MJ423]: (Josselyn) I concur with this recommendation.

3.7. Review of the Literature on Non-floodplain ("Unidirectional") Waters and Wetlands

Commented [M424]: (Murphy) I was a member of the CQ 5 a&b group so my comments/changes here more editorial.

Charge Question 5(a). Section 5.4 of the draft Report reviews the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters, including "geographically isolated wetlands," with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

The SAB finds that the review and synthesis of the literature on the downstream connectivity and effects of wetlands and open waters with the potential for unidirectional connectivity is generally thorough, technically accurate, and readable. As previously mentioned, the SAB recommends the authors reconsider use of the terms "unidirectional" and "geographically isolated wetlands". The SAB finds that the focus on hydrologic connections in Section 5.4 and elsewhere does not account for important biological exchanges, not transported stream flow, that can strongly influence the integrity of downstream waters. The SAB recommends that the Report be reorganized to reflect the types of connections between wetlands and downstream waters, including surface water, shallow ground water, deep ground water, and biological connections, with specific attention paid to the magnitude, duration, and frequency of these connections. The SAB recommends that spatial landscape position and scale be considered in the evaluation of the degree of connectivity, given that regional context (e.g., geology, climate, landforms, and surficial sediments) is a major driver of the temporal and spatial scales of hydrologic linkages. Consideration of landscape position and scale will likely provide further justification for treating wetland complexes as aggregates rather than as individual units based on geographic distribution. As previously discussed, the SAB also finds that human disturbance may change the type of connections as well as the magnitude, frequency, and duration of the connections. The SAB recommends that the draft Report be revised to acknowledge the role of humans in these changes. In addition the draft Report should discuss the differences between manmade wetlands and those found in natural settings.

3.7.1. Summary of the Literature on Non-floodplain ("Unidirectional") Wetlands

The SAB finds that the Report captures the most relevant peer-reviewed literature on "unidirectional wetlands" and "geographically isolated wetlands". While the Report already includes several major review papers, the SAB recommends adding ~~the 2013~~ a review paper~~, "Concepts of hydrological connectivity: research approaches, pathways and future agendas~~," by ~~L.J.~~ Bracken, et al. (2013). The SAB also recommends that additional citations on biological connections (e.g., Naiman et al 1994), especially those that address material flows generated by avian fauna, be added to the Report. ~~Findings from additional literature on the~~Evidence from the literature on biological exchanges between unidirectional wetlands and downstream waters created by major species assemblages (e.g., amphibians, birds, reptiles, and invertebrates) ~~are~~ is overwhelming and is particularly important to include. These biological exchanges potentially influence the biological integrity of downstream waters through bulk exchange of materials (e.g., energy, nutrients, and contaminants), introduction of disease vectors or other living matter, or provision of habitat essential for biological integrity and completion of life cycles of downstream species.

Recommendations

Commented [MM425]: (Murphy)

Commented [MM426]: (Murphy)

Commented [JT427]: (Tank) The term "human disturbance" should be changed to be consistent with previous sections of the SAB Review which discusses human alterations or human impacts- "disturbance" is a value-laden term.

Commented [MJ428]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [SF429]: (Fennessy) This reference is not in the References section (and others are missing as well?)

Commented [D430]: (Patten) I think this is stretching connectivity... this could connect almost any location.

Commented [LJ431]: (Johnson) Insert references provided by Rob Brooks here

Commented [LJ432]: (Johnson)

Commented [LJ433]: (Johnson)

- The literature review in Section 5.4 of the Report is generally thorough, technically accurate and readable; however, the SAB recommends that the ~~2013~~ review article by ~~L.J.~~ Bracken et al. (2013) be added to the Report.

- The EPA should ~~consider including~~ review additional publications on the subject of biological connections, some of which are referenced throughout this SAB report. Publications that analyze material flows generated by avian fauna will be especially important to review.

- The literature review should analyze the scientific literature to specifically address the relative degree of connectivity for various non-floodplain wetlands and describe the relative strengths of those connections for those wetlands. Geographic differences, especially as it relates to precipitation, should be analyzed.

- The SAB recommends that the EPA ~~also consider~~ review and, if needed, adding to the Report the following selected references that are particularly pertinent to the discussion of isolated wetlands: Brunet and Westbrook (2012); Croke et al. (2005); Conly et al. (2001); Fang and (2008); Gray et al. (1984); Hayashi and Van der Kamp (2000); Hayashi et al. (2003); Montgomery (1994); Shaw et al. (2012); Spence (2007); Spence and Woo (2003); Stichling and Blackwell (1957); Thompson et al. (2008); Van der Kamp et al. (2003); Van der Kamp et al. (2008); Wemple et al. (1996); Wemple et al. (2001); Wigmosta and Perkins (2001); Woo and Rowsell (1993); and Yang, et al. (2010).

3.7.2. Clarification of Terms in Section 5.4 of the Report

The SAB finds that the new term "unidirectional wetlands " as used in the Report implies on the presence of only one-way hydrologic flows, when in fact, connectivity can have many physical, chemical, and biological dimensions far beyond ~~-~~surface and shallow subsurface water flows. The SAB suggests that the draft Report's uni- and bi-directional terminology be replaced by terms that better describe landscape position. In this case, "bidirectional wetlands" would be redefined as those within riparian/floodplain settings~~floodplains~~, and "unidirectional wetlands" as those not within riparian/floodplains ~~a floodplain~~ (i.e., non-riparian/non-floodplain settings~~wetlands~~). The influence of riparian/floodplain and non-riparian/non-floodplain wetlands on downstream ~~connectivity~~connectivity can then be explained in the context of their landscape setting and with respect to the conceptual framework, as described below.

Recommendation

- The terms "unidirectional" and "geographically isolated" wetlands should be replaced in the Report with the term "non-riparian/non-floodplain wetlands."

3.7.3. Recommended Conceptual Framework for Synthesizing Types and Gradients of Connectivity

Commented [MM434]: (Murphy)

Commented [D435]: (Patten) this worries me...

Commented [MJ436]: (Josselyn) Suggested additional recommendation.

Commented [MM437]: (Murphy)

Commented [D438]: (Patten) do any of these references relate to connectivity of isolated wetlands through connections of deep aquifers that often support these wetlands and also influence down gradient rivers.

Commented [JM439]: (Meyer) Why are we using the term "isolated wetlands" here?

Commented [M440]: (Murphy) Needs to be reviewed with respect to other terminology revisions to uni- and bidirectional categories.

Commented [SF441]: (Fennessy)

Commented [MJ442]: (Josselyn) I concur with this recommendation.

Commented [SF443]: (Fennessy)

Commented [MJ444]: (Josselyn) See my comments on this section in the general comments on the draft report.

As discussed in the response to charge question 2, the SAB recommends the Report be revised to use a conceptual framework with multiple flowpaths that correspond to the multiple dimensions of connectivity. The five ~~functional flowpaths~~functions used to describe connectivity in the draft Report (i.e., source, sink, refuge, lag, transformation) are differentially affected by the type and characteristics of connections. The framework recommended by the SAB is envisioned as a potential way to map the five ~~functional flowpaths~~ functions across different regional settings in order to assess the consequences and relative extent of hydrologic, biological, and beneficial chemical ~~functions~~flowpaths provided by non-floodplain ("unidirectional") wetlands to downstream waters.

Similarly the SAB recommends that Figure 1, shown below, be used to frame the discussion about the type and gradient of various connections between and among floodplain wetlands and non-floodplain wetlands and downstream waters (or "bidirectional" and "unidirectional wetlands," respectively, using the Report's original nomenclature).

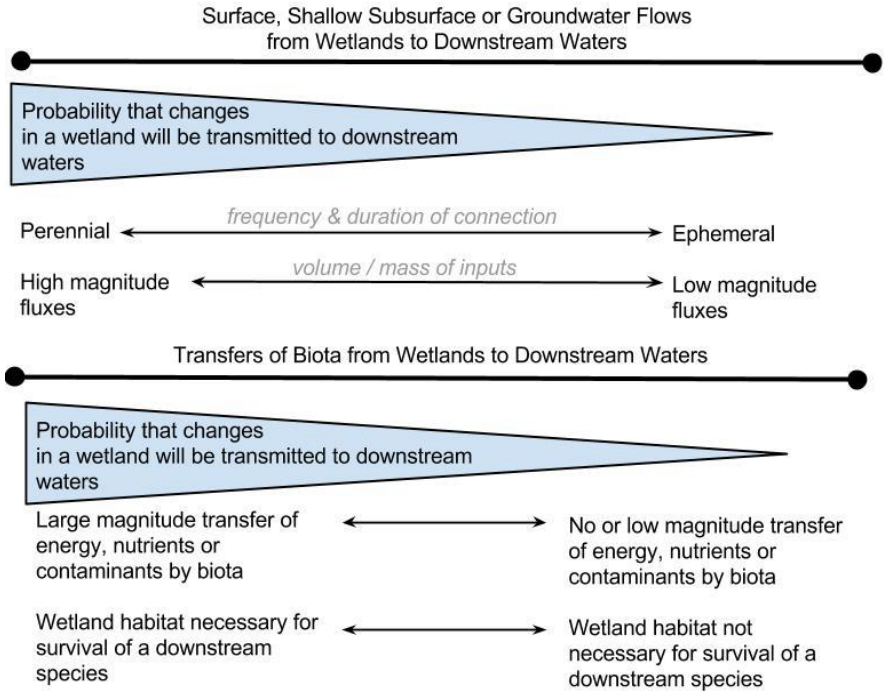

Figure 1: Framework representing the potential consequences of changes to downstream waters with increases in the magnitude, duration, and frequency of surface and subsurface connections.

The multiple dimensions of connectivity to downstream waters include connections provided by surface waters, ground water, chemical transformation, and biological functions. Each dimension of connectivity should be arrayed as a gradient, as illustrated in Figure 1. This approach could be used to synthesize findings from the literature in terms of the degree of connectivity pathways (e.g., magnitude,

Commented [M445]: (Murphy) I'm not certain that the flowpath discussed in CQ 2 response are the same as these five terms. I see the five flow paths as transport processes, i.e., (1) surface water (channelized and overland flow), (2) shallow ground water (hyporheic water, soil water uptake, unsaturated flow and infiltration), (3) chemical transformation, (4) biotic life cycle (production, reproduction, migration, decomposition) and (5) ground water (recharge, stream discharge, springs). Movement along flow paths is affected by the source, sink, refuge, lag and transformation modifiers that define the magnitude of the flux within the transport category.

Commented [GA446]: (Ali) For consistency purposes, we should decide whether we want to refer to "functions" or "functional flowpaths" when referring to source, sink, refuge, lag, and transformation. The reference to "functions" is more consistent with the revised framework proposed in the SAB report.

Commented [LJ447]: (Johnson) IS THIS CONSISTENT WITH THE NEW TERMINOLOGY?

Commented [JT448]: (Tank) It is unclear from this text whether new terminology (non-floodplain) or old terminology (bidirectional vs unidirectional) is being suggested. It would be clearer to recommend the switch, and stick with that terminology throughout the SAB Review.

Commented [MS449]: (Sullivan) It would be helpful if additional explanation related to the "probability that chanes in a wetland will be transmitted to downstream waters" were included in the figure caption.

Commented [KF450]: (Fausch) One modification that could improve this figure is to substitute "survival and persistence" for "survival" of a species in the bottom row of conditions. When habitats are lost or disconnected (or in some cases connected, for some amphibians and other organisms sensitive to fish predation), not only do they not survive for that generation, but the species is extirpated from that region.

Commented [DA451]: (Allan) The diagram is terrific.

Commented [JT452]: (Tank) I like this figure, but shouldn't it be suggested that it be introduced earlier in the Report? Perhaps it would be better located in Chapter 1: Conceptual Framework, otherwise these important concepts are not seen until the last chapter of the Report.

duration, frequency[1]) rather than just the presence of any connection. Endpoints for each gradient should be identified where possible. For example, terminal salt lakes and playas are examples of wetlands and open water bodies that have weak hydrologic connections. The SAB finds that such an analysis is possible and would be useful for summarizing the effects of such connections in semi-quantitative terms.

Recommendations

- When describing connectivity for floodplain and non-floodplain wetlands and certain open waters, the EPA should refer to the conceptual framework the SAB has recommended for the Report (see Section 3.2.3 of this report).

- The EPA should use Figure 1 in this SAB report to frame the discussion of connectivity gradients and magnitude, duration, and frequency of connectivity pathways among floodplain wetlands and non-floodplain wetlands and downstream waters.

- The EPA should identify endpoints for each connectivity gradient, and quantify each connection to the degree possible based on the scientific literature and provide specific statements on where the literature is lacking or incomplete.

3.7.4. Temporal and Spatial Scales of Connections among Non-Floodplain Wetlands and Open Waters

Temporal and spatial scales of connections among non-floodplain wetlands and open waters should be addressed explicitly with the magnitude, frequency, and duration of connections quantified whenever possible. In particular, the SAB recommends that the authors examine the degree of connectivity through a range of time scales (e.g., days versus thousands of years) to establish the magnitude, duration, and frequency of connections. For example, groundwater dynamics occur at a much longer time scales than those of surface and shallow subsurface flows. Consequently, groundwater connections, where they exist, may not have an immediate influence on downstream water. On the other hand, groundwater flows may be important in sustaining flows in rivers and streams during drought periods. High magnitude, short duration floods may infrequently connect non-riparian/non-floodplain wetlands with downstream waters and the subsequent effect on downstream waters may be short lived and inconsequential unless floods transfer a toxic pollutants, an invasive species, or pathogen with subsequent long-lived damaging effects. Such instances are likely to be unusual circumstances and case specific. Geographic differences across spatial scales are also important determinants of rainfall patterns and streamflow frequency; such effects should be evaluated using the scientific literature.

The SAB recommends that the authors consider including in the Report the following statement that reflects the temporal dynamics of connections of minimally connected wetlands: *Over sufficiently long time scales all aquatic habitats are connected to downstream waters through the transfer of water, chemicals or biota, yet the effects of these connections vary widely in magnitude across wetlands*. The SAB also recommends that the report discuss the various types of connectivity in terms of their *effect* on

[1] Note that, in this context, frequency, magnitude, and duration, apply to all five ~~functional flowpaths~~functions, and not to just hydrologic connectivity.

Commented [KK453]: (Kolm) Not accurate for all case histories: Terminal salt lakes and playas may also have strong hydrologic connections like we see in Nevada and Death Valley, CA. Recommend deliting the sentence or modifying it to include both end members.

General comment: Each of the case histories presented could use a cross-sectional diagram illustrating the hydrology and connectivity of the features and region. It is difficult for most readers to visualize these descriptions of structure and function.

Commented [MJ454]: (Josselyn)

Commented [MJ455]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [JM456]: (Meyer) This first sentence seems somewhat contradictory with the recommendation that EPA "assess connectivity in terms of downstream effects, not just in terms of frequency, magnitude, or duration of connections."

Commented [MS457]: (Sullivan) It seems like a predictability framework could also vbe helpful in understanding the degree of connectivityoutlined here (e.g., waterfowl migration moves nutrients at high magnitudes at relatively predictable intervals).

Commented [LB458]: (Benda) Although mentioned previously in these comments, the issue that all waters are connected over sufficiently long time scales is highlighted again using the scale "thousands of years". How many thousands of years? 1, 10, 100, 1000? If the SAB wants to encourage EPA to consider hydrologic-habitat connectivity at these extended time scales, perhaps it should provide some guidance on how to determine the strength of those connections, in the context of policy making which is the ultimate use of the EPA Connectivity Report. The issue of expanded time scales comes up in other areas of the SAB review including under "Recommendations" (Pg. 50, lines 6-7).

Commented [DA459]: (Allan) I feel this seemingly side-steps the issue of degree of connectivity and the gradient comcept.

Commented [LJ460]: (Johnson)

Commented [SF461]: (Fennessy)

Commented [D462]: (Patten) we have this recommendation earlier but does this weaken the connectivity argument as it can be interpreted as geological time (e.g., millennia).

Commented [DA463]: (Allan) Although this statement acknowledges variation in magnitude of connectivity, I think the SAB review should direct the EPA Report towards greater specificity, rather than towards very general statements that provide little guidance on the degree of connectivity. Might this be an opportunity to suggest that, while all systems are connected, the strength of connectivity is affected by many variables and is best decided on a case-by-case basis?

downstream water quality and biological integrity, not just in terms of frequency or magnitude. That is, low frequency or high magnitude events can "re-set" biological and ecological functions in important ways. A summary of such effects could be gleaned from the literature or from examples provided in the Report's case studies.

Recommendations

- The EPA should recognize in the Report that all aquatic habitats are likely to be connected to downstream water (in various magnitudes) over sufficiently long time scales~~.~~, yet the effects of these connections vary widely in magnitude across wetlands.

- The EPA should assess connectivity in terms of downstream effects, ~~not just in terms of~~ based upon the frequency, magnitude, ~~or~~ and duration of connections.

- The Report should emphasize that while that all aquatic habitats are connected to downstream water (in various magnitudes) over sufficiently long time scales, such connections may not be relevant if they do not have important effects on downstream water quality. As a result, the Report should access connectivity in terms of those downstream effects with an emphasis on frequency, magnitude, and duration of connections.

3.7.5. Assessing Wetland Connectivity Based on Aggregate Analysis of Wetland Complexes

Assessment of the degree of wetland connectivity is best conducted on aggregated wetland complexes rather than on individual wetlands because over a range of precipitation regimes the boundaries of any single wetland may vary through space and time~~.~~ (e.g., Drexler et al. 2013).. The regional context (e.g., geology, climate, landforms, and surficial sediments) is a major driver of the temporal and spatial scales of hydrologic linkages. Thus, regional context and spatial landscape position and scale should also be considered when evaluating the degree of connectivity, e.g., distance from and size of wetlands (or similar wetland types). The SAB notes that various frameworks for regionalization exist and include characterizations of landscapes at nested scales, such as regional, sub-regional, and local. These nested scales can be used to summarize variability in connectivity identified in the peer-reviewed literature.

Recommendations

- The Report should be clearly explain why, and recommend that, wetland connectivity must be assessed in terms of aggregated wetland complexes, rather than individual wetlands.

- The Report should discuss the usefulness of regionalization methods to summarize information about wetland connectivity at nested scales.

- The Report should analyze the scientific literature to determine if there is an appropriate scaling that should be used for determining how non-floodplain wetlands may be aggregated when considering their effects on downstream waters. A discussion on the how the scaling may vary geographically and based on factors affecting connectivity should be included.

Commented [M464]: (Murphy) Without the second clause this is an entirely different recommendation!

Commented [MM465]: (Murphy)

Commented [MM466]: (Murphy)

Commented [MJ467]: (Josselyn) I suggest this to replace the two bullets above..

Commented [MJ468]: (Josselyn) See my comments on this section in the general comments on the draft report

Commented [DA469]: (Allan) I am not sure that the aggregate effect of wetland complexes is analogous to the aggregate effect of ephemeral headwater streams (this parallel is not states as such but the reference to wetland complexes seems parallel to earlier treatment of stream networks). Are wetlands always iin complexes? Should a lone wetland be protected?

Commented [SF470]: (Fennessy) It seems that the hydroperiod of a wetland may vary, but boundaries are thought to be more fixed, particularly as defined by the occurrence of hydric soils, which will be observable across many years (and is the basis for wetland delineation).

Commented [AA471]: (Aldous)

Commented [SF472]: Could the HLRs be used as an example? Or the USGS HUC systems

Commented [MJ473]: (Josselyn) Suggested additional recommendation.

3.7.6. Discussion of Human Alteration of Landscapes in Section 5.4 of the Report

The Report tends to focus on natural wetland systems or those with minimal disturbance. As previously discussed, human disturbances (and related legacy effects) alter the type, strength and magnitude of connectivity pathways. Some types of disturbances promote connections where none previously existed, others alter existing types of connections or trigger the transport of novel chemical or biological species. Creating connections where none previously existed, or where they were of low frequency through time, can affect the biological integrity of downstream waters. For example, such connections can be a key problem for amphibians that must breed and rear in wetlands free of fish (i.e., vernal pools). There is a large literature on the importance and conservation of ephemeral habitats for amphibians and other species and functions (Calhoun and deMaynadier 2008; Semlitsch 1998, 2000, 2002; Semlitsch and Bodie 2003). Most of these references are from the eastern U.S. There is a suite of species, mostly toads, that rely on ephemeral aquatic habitats in the west and Great Plains region, but they are less well known. In addition, there are many instances where man-made isolated wetlands occur within the landscape. These features are often found behind levees or within isolated parcels within urban landscapes and do not provide the same ecosystem functions as natural wetlands. The SAB recommends that Section 5.4, as well as other sections of the Report acknowledge these types of alterations or man-made habitats and include a discussion of current and past (legacy) human disturbances and how they alter the type, strength, and magnitude of connectivity pathways. In particular, human activities such as water diversion or water extraction may influence the water table, thereby reducing the potential for connections within and among wetlands and downstream waters. In particular, extractive activities or those that alter hydrologic flow paths (diking, channelization, damming) may influence the magnitude of natural disturbances such as floods or droughts.

Recommendation

- Section 5.4, and other sections of the Report, should be revised to discuss the legacy effects of human disturbances and their effect on the type, strength, and magnitude of connectivity pathways and to describe to the degree possible how connectivity may have been reduced or eliminated by such human disturbances.

3.8. Review of the Findings and Conclusions Concerning Non-floodplain ("Unidirectional") Waters and Wetlands

Charge Question 5(b). Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 5(a) above. Please comment on whether the conclusions and findings in section 1.4.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

In responding to EPA's findings and conclusions regarding connectivity among open waters and unidirectional (non-floodplain) wetlands and downstream waters (Section 1.4.3 of the Report), the SAB focused on knowledge drawn from the peer-reviewed literature, especially that: (1) connectivity extends beyond hydrologic connectivity, (2) each connectivity flowpath can be described as a gradient that varies over space and time, and (3) that each connectivity flowpath contributes to the downstream effects of multiple connectivity flowpaths.

Commented [MJ474]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [KF475]: (Fausch) Additional text.

Commented [DA476]: (Allan) Human alterations heere focus on man-made wetlands rather than human alterations to waters – quite different from previous sections on human alterations. See my comments on human alterations in the general comments on the rdraft report.

Commented [JT477]: (Tank) Again, consistent terminology associated with human impacts should be used here and across all sections of the SAB Review- human "alteration" or "impact" is preferable to "disturbance" in my opinion.

Commented [LJ478]: (Johnson)

Commented [MJ479]: (Josselyn) Suggested addition.

Commented [M480]: (Murphy) Just want to repeat that recommending changes in the chapter implies that there will be changes in the conclusions and Executive Summary. I think these questions need to be answered in a single section to avoid ambiguities in the text.

Commented [MJ481]: (Josselyn) See my comments on this section in the general comments on the draft report.

3.8.1. Scientific Support for the Conclusions Concerning Waters and Wetlands with Potential For Unidirectional Hydrologic Flows to Rivers and Lakes

The SAB disagrees with the overall conclusion in Section 1.4.3 of the Report (Conclusion 3) indicating that, "The literature we reviewed does not provide sufficient information to evaluate or generalize about the degree of connectivity (absolute or relative) or the downstream effects of wetlands in unidirectional landscape settings." This statement is inconsistent with the text immediately preceding it, which describes numerous scientifically-established functions of non-floodplain wetlands that can benefit downstream water quality and integrity. Furthermore, the conclusion largely overlooks the effect of biological connections on downstream waters. The SAB finds that the scientific literature provides ample information to support a more definitive statement, and strongly recommends that the authors revise this conclusion to focus on what is supported by the scientific literature and articulate the specific gaps in our knowledge that must be resolved (e.g., degree of connectivity, analyses of temporal or spatial variability).

The SAB recommends that Conclusion 3 in the Report explicitly recognize connectivity as a gradient rather than a dichotomous, categorical variable. The SAB recommends that the following text be included in Conclusion 3 in order to highlight the fact that there are multiple mechanisms resulting in connectivity, and these occur over gradients of both space and time.

> *"Over sufficiently long time scales all aquatic habitats are connected to downstream waters through the transfer of water, chemicals or biota, yet the magnitude and effects of these connections vary widely across wetlands."*

The SAB recommends that all of the Report's conclusions encompass connections beyond hydrologic ones, and that the frequency, magnitude, and duration of these connections be considered as well as their predictability. The SAB recommends that within the text of Conclusion 3 in the Report, the authors explicitly state the four pathways by which unidirectional wetlands can be connected to downstream waters: via surface water, shallow subsurface or groundwater flowpaths, or through the movement of biota. It is the magnitude and effect of material, water or biotic fluxes rather than the simple presence or absence of a flux that determines the strength of the connection between a wetland and downstream waters.

The SAB disagrees with the notion that even minimal hydrologic connections are more important than biological connections, no matter how large the flux. The SAB recommends that this emphasis must shift in order to account for strong connections ~~along~~that affect any one of the ~~four pathways of connection.~~five functions used to describe connectivity in the EPA Report. If the goal of defining and estimating connectivity is to protect downstream waters, the interpretation must move from a dichotomous, categorical distinction (connected vs. not connected) towards a gradient approach that recognizes variation in the strength, duration and magnitude and effect of those ~~connections.~~connections. The SAB recommends that an integrated systematic approach be taken to conceptualize the structure and function of non-floodplain ("unidirectional") wetlands. The systems approach is used by hydrogeologists, and by surface water and groundwater hydrologists, who have the quantitative tools and conceptual models to determine the connectivity of both surface and subsurface hydrological systems to unidirectional wetlands (ASTM, 1996; Kolm, et. al, 1996), and can be extended to include biological connections and HGM wetland classifications (Kolm et.al,. 1998).

Commented [M482]: **(Murphy)** This conclusion of the EPA Report ONLY arises from EPA's use of a dichotomous and categorical definition of connectivity. It has no scientific justification. If gradational connectivity is used then wetlands not connected to downstream WUSA would simply be those that have a vanishingly small degree of connectivity to such downstream WUSA. The criteria for such a de minimus status could be set as conservative as EPA and stakeholders felt necessary for the protection of human and ecological health...

Commented [MJ483]: **(Josselyn)** See my comments on this section in the general comments on the draft report.

Commented [D484]: **(Patten)** it also overlooks deep aquifer connections that support isolated wetlands and that are connected to rivers or other larger water bodies.

Commented [D485]: **(Patten)** for example???? years, decades, centuries... etc.

Commented [MS486]: **(Sullivan)**

Commented [AA487]: **(Aldous)** Needs to be clarified whether this prioritization was stated in the EPA report or implied.

Commented [KF488]: **(Fausch)** This is a key point and could be emphasized in the Executive Summary. Many of these biological fluzes have not yet been measured.

Commented [M489]: **(Murphy)** Four or five? In any case, needs to be consistent with rest of SAB report.

Commented [D490]: **(Patten)** this explanation does not necessarily support our disagreement with the statement that minimal hydro connections are more important than biological connections.

Commented [KK491]: **(Kolm)** Additional text.

Recommendations

- The overall conclusion for floodplain and non-floodplain wetlands (Conclusion 3 in Section 1.4.3) should be revised to focus on what is supported by the scientific literature and to provide more specifics on what still needs to be resolved (e.g. degree of connectivity, analyses of temporal or spatial variability).

- The following text should be included in Conclusion 3 of the Report: *"Over sufficiently long time scales all aquatic habitats are connected to downstream waters through the transfer of water, chemicals or biota, yet the magnitude and effects of these connections vary widely across wetlands."*

- All of the Report's conclusions should encompass connections beyond hydrologic connectivity (i.e., to include biotic connections), and the frequency, magnitude, and duration of these connections should be considered.

- Conclusion 3 of the Report should explicitly state the ~~four~~five pathways by which non-floodplain wetlands can be connected to downstream waters: i.e., via surface water, shallow subsurface flowpaths or groundwater flowpaths, or through the movement of biota.

- The conclusions in the Report should state that connectivity is based on the magnitude and effect of water, material, and biotic fluxes to downstream waters.

- The SAB recommends that assessment of connectivity be revised from a dichotomous, categorical distinction (connected vs. not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude, and effect of those connections.

3.8.2. Recommendations Concerning Findings for Waters and Wetlands with Potential For Unidirectional Hydrologic Flows to Rivers and Lakes

The SAB provides a number of recommendations to improve the presentation of findings in Section 1.4.3 of the Report.

The SAB recommends that, as has been done for prior conclusions, the authors remove references to specific studies within the text of the key findings. The Report's conclusions are intended to summarize general themes arising from a broad synthesis of diverse literature. The SAB finds that it is not necessary to attribute these overarching findings to one or a few specific studies. Further, the SAB recommends that the key findings be short and concisely stated.

The SAB also recommends that the key findings be more explicitly presented in the text of the Report. Conclusions about non-floodplain wetlands are summarized in Table 5-4, but these same summary points are not clearly explained in the text itself. In addition, Table 5-4 discusses functions of wetlands but does not present conclusions on how those functions translate to an effect on downstream water quality based on the magnitude or duration of any of the modes of connection discussed in the literature. For example, the statement that "unidirectional wetlands can remove, retain, and transform many

Commented [JT492]: (Tank) It is notable that this is the only section of the SAB Review that explicitly offers alternative text or text replacement. I am very supportive of the suggested changes, but am wondering how it will be perceived, given that no other sections offered up such specific text edits.

Commented [MJ493]: (Josselyn) See my comments on this section in the general comments on the draft report.

Commented [M494]: (Murphy) I'm not certain this has been done but there should be no more "justifying" in conclusions. That should be completed in the discussion. Conclusions need to be concise, declarative statements.

nutrient inputs" refers to such functions, but there is no conclusion about how these would affect downstream waters.

The SAB recommends that the EPA revise several of the key findings in Section 1.4.3 of the Report. These revisions are consistent with the literature synthesis performed and the SAB's knowledge of the subject.

Key Finding a

The SAB agrees with this general statement about the hydrosphere and general interconnectivity of wetlands and has no recommendations for changes in the existing text.

Commented [LJ495]: (Johnson) I think we can delete this, and include comments only on the key findings that require changes.

Key Finding b

The SAB recommends including the following statement in the Report as an additional key finding on the *biological functions* of unidirectional wetlands:

> *"Wetlands provide unique and important habitats for many organisms, both common and rare. Some of these organisms require multiple types of waters to complete their full life cycle, including downstream waters. Other organisms, especially abundant and/or highly mobile species, play important roles in transferring energy and materials between wetlands and downstream waters."*

Commented [KF496]: (Fausch) It might be best to clarify for the reader what is meant by multiple types of waters.

Commented [MS497]: (Sullivan)

The SAB also notes that the Report's conclusion on the similarity between wetlands and water bodies needs further substantiation from the literature as the functions within each are quite different, especially in nutrient and organic matter production. In addition, this conclusion should recognize the differences between natural wetland systems and those that~~which~~ are man-made or are found in urban environments. The functions and values of these man made wetlands may be severely compromised or absent and therefore may not similarly influence downstream waters as natural wetlands may have.

Commented [KF498]: (Fausch)

Commented [SF499]: (Fennessy) We want to be careful about urban wetlands – even very degraded wetlands have functions, in some cases they function at lower levels than a non-urban wetlands (for instance, support of a diverse array of species) but in some cases they function at higher levels (e.g., flood control). In addition, urban sites have the potential for education and the amenity of green space. I agree with the point that they may not have similar influence downstran, but they do have function/value.

Key Finding c

The SAB recommends including the following statement in the Report as an additional key finding about unidirectional wetlands and downstream waters to parallel the preceding finding on "hydrologic connectivity":

> *"Biological connectivity can occur between [non-floodplain] wetlands and downstream waters through two major mechanisms: 1) activities of biological organisms within wetlands, and 2) movements of animals and plants. Activities of biological organisms within wetlands (e.g., foraging, breeding, roosting) can change the amount, concentration, and spatial density of organic and/or inorganic components within the water column or soils, which can be transmitted down-gradient by fluxes of surface water or groundwater. Movements of animals (i.e., macroinvertebrates, fish, amphibians, reptiles, birds, mammals) and plants (i.e., seeds, propagules, including colonization by invasive species or pathogens) can also occur among waters with varying magnitude, frequency, duration, and distance. Many species in these groups that use both stream and wetland habitats are capable of dispersal distances equal to or greater than distances between many [non-floodplain] wetlands and river networks. Migratory*

> *waterbirds (e.g., waterfowl, shorebirds, waders, and colonial species) can be an important vector of long-distance dispersal of plants, invertebrates, parasites, and pathogens between these waters and the river network. In addition, the magnitude of translocated biomass and nutrients can be substantial, when large numbers of individuals move temporarily, periodically, or permanently between waters."*

Key Finding d

The SAB has no recommendations for changes in the existing text.

Key Finding e

The SAB has no recommendations for changes in the existing text.

Key Finding f

The SAB recommends including the following two additional key findings that summarize important information from the main body of the document that was not emphasized in the original wording of the key ~~findings~~finding f.

> Suggested additional key finding on *spatial proximity* of non-floodplain wetlands: *"Spatial proximity is an important determinant of the magnitude, frequency and duration of connections between wetlands and streams that will ultimately influence the fluxes of water, materials and biota between wetlands and downstream waters."*
>
> Suggested additional key finding on the *cumulative or aggregate impacts* of non-floodplain wetlands: *"The cumulative influence of many individual wetlands within watersheds can strongly affect the spatial scale, magnitude, frequency, and duration of hydrologic, biologic and chemical fluxes or transfers to downstream waters. Because of their aggregated influence, any evaluation of changes to individual wetlands should be considered in the context of past and predicted changes (e.g., from climate change) to other wetlands within the same watershed."*

The SAB recommends that the Report authors cite the following references in support of this last statement: Preston and Bedford (1988); Lee and Gosselink (1988).

Recommendations

- The authors should remove references to specific studies within the text of the key findings in the Report. The Report's conclusions are intended to summarize general themes arising from a broad synthesis of diverse literature.

- The key findings should be more explicitly presented in the text of the Report. Conclusions about unidirectional wetlands are summarized in Table 5-4, but these same summary points are not clearly explained in the text itself.

- The SAB recommends revising several of the key findings in Section 1.4.3 of the Report (see recommended text above).

Commented [D500]: (Patten) this statement ultimately connects most wetlands and rivers regardless of proximity or any close geographic locations.

Commented [LJ501]: (Johnson) Delete

Commented [MS502]: (Sullivan) We may consider qualifying this additional key finding related to spatial proximity to point out that greater distances do not necessarily equate to less or no connectivity.

Commented [LJ503]: (Johnson)

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APPENDIX A: THE EPA'S CHARGE QUESTIONS

Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence

Technical Charge to External Peer Reviewers

Understanding the physical, chemical, and biological connections by which streams, wetlands, and open-waters affect downstream waters such as rivers, lakes, and oceans is central to successful watershed management and to meeting water quality goals. It is also central to informing policy decisions that guide our efforts to meet these goals. The purpose of this Report, titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* is to summarize the current scientific understanding of broadly applicable ecological relationships that affect the condition or function of downstream aquatic ecosystems. The focus of the Report is on small or temporary non-tidal streams, wetlands, and open-waters. Examples of relevant connections include transport of physical materials such as water or wood, chemical compounds such as nutrients or pesticides, movement of biological organisms such as fish or insects, and processes or interactions that alter material transport, such as nutrient spiraling. Materials reviewed in this Report are limited to peer reviewed scientific literature. Findings from this Report will help inform EPA and the U.S. Army Corps of Engineers in their continuing policy work and efforts to clarify what waters are covered by the Clean Water Act. As a scientific review, the Report does not consider or make judgments regarding legal standards for Clean Water Act jurisdiction.

The Report is presented in six chapters. Key findings and major conclusions are summarized in Chapters 1 (Executive Summary) and 6 (Conclusions and Discussion). Chapter 2 (Introduction) describes the purpose and scope of the document and the literature review approach. Chapter 3 presents a conceptual framework that describes the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and watershed climatic factors that influence connectivity at various temporal and spatial scales. Chapter 4 surveys the literature on stream networks with respect to physical, chemical, and biological connections between upstream and downstream habitats. Chapter 5 reviews the literature on connectivity and effects of non-tidal wetlands and certain open waters on downstream waters. All terms are used in accordance with standard scientific meanings, and definitions which are in the Report glossary.

TECHNICAL CHARGE QUESTIONS

Overall Clarity and Technical Accuracy of the Draft Report

1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*.

Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

2. Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this chapter and its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

3(a) Chapter 4 of the Report reviews the literature on the *directional* (*downstream) connectivity and effects* of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

3(b) Conclusion (1) in section 1.4.1 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3(a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

4(a) Section 5.3 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review

objectives of the Report, and any corrections that may be needed in the characterization of the literature.

4(b) Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

5(a) Section 5.4 of the draft Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters, including "geographically isolated wetlands," with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

5(b) Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 5(a) above. Please comment on whether the conclusions and findings in section 1.4.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

APPENDIX B: TECHNICAL AND EDITORIAL CORRECTIONS FOR THE FINDINGS AND CONCLUSIONS

Recommended Wording for Section 1.4.2

- Use "waters and wetlands in riparian/floodplain settings" throughout
- Page 1-9 line 9. After "and maturation habitat for stream insects" add, "and thus form integral components of river food webs" or other language that underscores food-web connectivity.
- Page 1-9 line 15, bullet a. Delete first sentence. Strive for consistency in terminology; i.e., suggest using "waters and wetlands in riparian/floodplain settings".
- Page 1-9 line 21, bullet a. Delete "some".
- Page 1-9 line 25, bullet b. Is "densely" needed? Suggest "variably".
- Page 1-9 line 35, bullet c. Specify waters and wetlands in riparian/floodplain settings in lead sentence.
- Page 1-9 line 35, bullet c. Suggest "storing and subsequently releasing" rather than "desynchronizing".
- Page 1-10 line 3, bullet d. Lead with "Waters and wetlands in riparian/floodplain settings".
- Page 1-10 lines 5-6, bullet d. This example looks like an agricultural BMP and may not be appropriate. Suggest revisiting p 5-7 lines 24-35 for a more relevant example.
- Page 1-10 line 7, bullet e. Lead sentence emphasizes ecosystem function but body of paragraph describes biological connectivity. This might require a different lead sentence or an additional bullet on functional components/processes.
- Page 1-10 line 23, bullet e. Suggest including the importance of waters and wetlands in riparian/floodplain settings to birds, and how birds can spatially integrate the watershed landscape.

Recommended Wording for Other Sections

- Use "waters and wetlands in riparian/floodplain settings" throughout.
- Page 5-37 top paragraph lines 6-17. This is a strong paragraph and may be preferable to the opening paragraph of 1.4.2. At least try to get some of these points into the opening of 1.4.2.
- Table 5.3. Bullets use "riparian areas" and it would be preferable to call out "waters and wetlands in riparian/floodplain settings." The second bullet appears to be bit over generalized, as there can be high variability in lateral flow and exchange along the drainage network (e.g., beads on a string). Also, if the text in this chapter on riparian areas is moved to the streams chapter and replaced with other material, further changes may be needed.
- Page 6-1 lines 23-34. This additional conclusion section is fine, but again check for consistency of terms. Also, sediments are identified as both a source and sink in the same paragraph. Most commonly they are a sink. It might be preferable to refer to sediment exchange influencing channel dynamics.
- Page 6-1 line 30. Suggest connecting nursery habitat to healthy downstream populations. Also suggest reinforcing that waters and wetlands in riparian/floodplain settings are tightly coupled through food-web linkages. Role and importance of birds should also be mentioned.