April 05, 2019

Mr. Andrew R. Wheeler
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Mr. R.D. James
Assistant Secretary of the Army for Civil Works
U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20314

Via regulations.gov: Docket ID No. EPA-HQ-OW-2018-0149

Re: Revised Definition of "Waters of the United States" (84 FR 4154; Docket ID No. EPA-HQ-OW-2018-0149)

CC: Michael McDavit, Oceans, Wetlands, and Communities Division, Office of Water, EPA
Jennifer A. Moyer, Regulatory Community of Practice, U.S. Army Corps of Engineers

Dear Administrator Wheeler and Assistant Secretary James:

As members of the previous EPA Science Advisory Panel that reviewed both the Connectivity Report and the 2015 Clean Water Rule, we respectfully submit the following comments in response to the proposed Rule "Revised Definition of 'Waters of the United States" (84 FR 4154; Docket ID No. EPA-HQ-OW-2018-0149), published in the Federal Register on February 14, 2019.

INTRODUCTORY COMMENTS

The intent of the United States Federal Water Pollution Control Act (1972), more commonly known as the Clean Water Act (CWA), is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Act, 33 U.S.C. 1251 *et seq.*, Sec. 101, p. 3). However, the CWA is notably silent on what constitutes "the Nation's waters", more commonly called "waters of the United States" (WOTUS), and the geographic extent of WOTUS subject to regulation under the CWA has been debated for decades between the federal agencies and the regulated public, often adjudicated by the courts. The CWA was clearly intended to cover the traditionally navigable waters (TNWs), such as navigable rivers, lakes, and territorial seas. What is not clear is the extent to which CWA also was intended to cover the waters that are connected or otherwise contribute to the integrity of those TNWs, like wetlands and stream tributaries.

In recent years, connectivity has emerged as a cornerstone theme – that is, if a wetland or tributary is connected to a TNW, then that wetland or tributary may also be a WOTUS. In 2015, the Obama administration sought to bring new clarity to the debate, promulgating the Clean Water Rule (CWR). The CWR was based on the best available science on waterbody

connectivity, supported by a review of >1,200 peer-reviewed scientific publications by 17 federal agency authors ("Connectivity Report"; USEPA 2015) and subsequently reviewed by 49 technical experts, including a 25-member Scientific Advisory Board (SAB), which was charged with conducting a public review of both the Connectivity Report (USEPA 2014) and the CWR. Since that time, substantial additional literature has emerged that reaffirms the scientific conclusions and recommendations of the SAB, which broadly supported both the Connectivity Report and the resulting CWR (e.g., Cohen et al. 2016, Rains et al. 2016, Fritz et al. 2018, Harvey et al. 2018, Leibowitz et al. 2018, Schofield et al. 2018, Colvin et al. 2019).

On December 11, 2018, the Trump Administration proposed a revised definition of WOTUS, which would replace both the CWR and other pre-CWR regulations (Revised Definition of "Waters of the United States", 84 Fed. Reg. 31, February 14, 2019). The proposed WOTUS Rule (hereafter, "proposed Rule") would remove or decrease protection for our Nation's waters, including thousands of miles of streams and millions acres of wetlands that are critical for sustaining water quality and healthy watersheds (Colvin et al. 2019). If passed, some of our most vulnerable waters (*sensu* Creed et al. 2017) would lose protection, including ephemeral streams (i.e., those that flow periodically, after precipitation events) and non-floodplain wetlands (i.e., those with no direct surface water connection to a navigable water).

As members of the former SAB panel that reviewed the Connectivity Report and the subsequent 2015 CWR, we strongly oppose the proposed Rule. The justification for the proposed Rule ignores or misrepresents much of the Connectivity Report and subsequent SAB review, and draws incomplete or incorrect conclusions. Therefore, the proposed Rule is inconsistent with the best available and most current science. It relies on case law, rather than a solid scientific understanding of waterbody connectivity and the complexity of drainage network and watershed processes, and the key functions that streams and wetlands provide, from local to watershed scales. Ephemeral streams, as well as non-floodplain wetlands would lose protection, and the proposed Rule opens the door for future loss of protections for intermittent streams. The net result is a rule that would have severe and long-lasting negative consequences for water protection and environmental conditions throughout the U.S.

Here, we provide a summary of concerns assembled by some members of the former SAB panel, which are described in detail below:

- The 2015 CWR is based on an established science of waterbody connectivity supported by the Connectivity Report and buttressed by recent literature. The proposed Rule is not based on sound science, nor does it provide any comparable body of peer-reviewed science to support the proposed changes.
- The proposed Rule rests on physical, hydrologic connectivity, and ignores chemical and biological connectivity, which is in direct contrast with the intent of the CWA to protect chemical, physical, *and* biological integrity.
- The proposed Rule misinterprets recommendations made by the SAB, and fails to recognize that even low levels of connectivity can be important relative to impacts on the chemical, physical, and biological integrity of downstream waters.
- The proposed Rule's grounding in structural connectivity is weak and its treatment of functional connectivity is non-existent.

- The proposed Rule ignores groundwater connectivity and fails to account for broad watershed processes and the cumulative, aggregate effects of waterbodies.
- Although the agencies (US Environmental Protection Agency [US EPA] and Department of the Army [Army]) state that the proposed Rule would establish jurisdiction under the CWA in a clearer and more understandable way, the proposed Rule is, in fact, unclear.
- The proposed Rule seems to leave open the possibility that human activities can lead to removal of protections for intermittent streams and additional wetlands.

DETAILED COMMENTS

The proposed Rule opposes and misinterprets previous recommendations. The proposed Rule is fully at odds with the EPA's own scientific Connectivity Report, which included 17 authors and 49 reviewers (USEPA 2015). The Connectivity Report is mentioned briefly, and then set aside. In cases where the agencies (US Environmental Protection Agency [US EPA] and Department of the Army [Army]) refer to science, they cherry-pick from the SAB Review, misinterpreting and taking information out of context.

For instance, the agencies specifically refer to a conceptual model developed by the SAB that illustrates how gradients in connectivity might be used to evaluate downstream impacts of changes to streams and wetlands. They used this model to argue for reduced protection for non-floodplain wetlands and ephemeral streams (USEPA 2014, Fig. 3, pg. 54). In doing so, the proposed Rule misrepresents the conceptual model and arrives at an erroneous conclusion not supported by the science, and opposite the intent of the SAB. In fact, the SAB stated that intermittent and ephemeral streams and non-floodplain wetlands are less likely to transmit degrading effects such as sediment and toxic chemicals to downstream waters compared to perennial streams and floodplain wetlands. However, the SAB also emphasized that ***even low levels of connectivity can be important relative to impacts on the chemical, physical, and biological integrity of downstream waters***. In fact, the lack of connectivity between some wetlands and downstream waters is a key reason they contribute to improved water quality (Marton et al. 2015). For instance, non-floodplain wetlands that trap stormwater or agricultural runoff store water and capture materials and nutrients, preventing or reducing pollution to downstream waters.

The SAB Review also highlights the importance of the cumulative, aggregate effects of streams and wetlands on downstream waters, which has not been recognized in the proposed Rule. For example, even though non-floodplain wetlands are typically located more distant from TNW, and ephemeral streams flow less frequently than intermittent or perennial ones, these wetlands and stream channels are often extremely abundant and widespread. As a result, just as ignoring the critical role played by tiny capillaries in our vascular systems can spell disaster for a human body, destroying or degrading non-floodplain wetlands and ephemeral streams can have drastic effects for watersheds, water quality, water supply, and key organisms like fish (Evenson et al. 2015, Lane et al. 2018). And like small capillaries in the human body, small tributaries comprise 60-80% of the total length of streams in watersheds, varying by geographic region (Nadeau and Rains 2007, Levick et al. 2008). Because of these important contributions, the SAB

recommended a case-by-case analysis to determine the degree of connection, which was adopted by the 2015 CWR.

The proposed Rule does not account for broader watershed processes. In proposing the WOTUS Rule, the agencies claim improved clarity and ease of implementation of the CWA. Although we agree that clarity and ease of implementation are important, the proposed Rule does nothing to increase the clarity of WOTUS, while it comes at the expense of sound decision-making informed by science. The "chemical, physical, and biological integrity of the Nation's waters" are inherently complex issues, resulting from myriad interactions among climate, geology, topography, land use, land cover, and the many contributing chemical, physical, and biological processes, all influenced by human actions (e.g., water withdrawal, development, climate change) (Amoros and Bornette 2002, Leibowitz et al. 2018). The presumption that a citizen or landowner can easily identify, demarcate, and distinguish a federally-regulated "water" from an unregulated one is unrealistic. These same citizens and landowners repeatedly call upon professionals for their planning, engineering, and accounting expertise. This notion of technically identifying waters by laypersons simply will not be possible under the proposed Rule.

A key recommendation of the SAB panel was to view waterbodies as part of interconnected river-riparian landscapes (Fausch et al. 2002, Wiens 2002, Tagwireyi et al. 2017, Harvey et al. 2018) and groundwater basins (Gorelick and Zheng 2015), thus highlighting the critical nature of these connections that are essential to understand the impacts of altered connectivity to downstream waters. For example, ephemeral and intermittent streams make up 59% of all streams in the conterminous United States (Nadeau and Rains 2007), and in the arid and semi-arid Southwest they comprise of more than 81% of all streams (Levick et al. 2008). As such, they are critically important in maintaining water quality, biodiversity, and overall watershed function (Levick et al. 2008, USEPA 2014, Colvin et al. 2019).

The proposed Rule's definition of structural connectivity is inadequate. Connectivity is dictated by structural aspects (e.g., the spatial configuration and contiguity of habitat or other physical units) as well as functional aspects (e.g., the functional interactions between units, which might be species or landscape elements). Functional connectivity, such as the movement of sediment from upstream to downstream in river networks (Petts and Amoros 1996), is critically important to waterbody connectivity, as recognized both by the SAB (USEPA 2014) and more recent literature (e.g., Cohen et al. 2016, Fritz et al. 2018). Both structural and functional aspects mediate the export or import of mass, energy, and biota from one waterbody to another, and the consideration of structural connectivity only, at the expense of functional aspects, is insufficient and often times misleading (Ali et al. 2018, Rinderera et al. 2018). In addition to surface water connections, there are multiple other elements of structural connectivity. For instance, streams are connected to downstream waters through networks of continuous beds and banks; yet the agencies propose to eliminate the use of bed, banks, and an ordinary high water mark to define a tributary.

The proposed Rule disregards functional connectivity. The proposed Rule's criteria for waters in floodplains requiring a direct surface hydrologic connection to jurisdictional waters are an example of the flawed science used in the proposed Rule that ignores how waters function. The spatial extents of floodplains scale with the size of their adjacent rivers, and the degree of

overbank flooding can be highly variable over time. Yet, even floodplain wetlands, lakes, and ponds that do not have a direct hydrologic surface connection "in a typical year", as stipulated by the proposed Rule, can be functionally important to downstream waters, as highlighted by the SAB (USEPA 2014). The SAB also clearly articulated the importance of recognizing *gradients* of waterbody connectivity (vs. a binary property: connected, not connected) that operate as a function of frequency, duration, magnitude, and predictability (USEPA 2014). More recent scientific literature has only buttressed this conclusion (e.g., Fritz et al. 2018, Leibowitz et al. 2018), yet the proposed Rule removes all non-floodplain wetlands and ephemeral streams from protection, irrespective of their degree of connectivity and the consequences of alterations to that connectivity to the chemical, physical, and biological integrity of downstream waters. The agencies propose to establish hard jurisdictional lines, counter to established and growing scientific evidence that waterbody connectivity and other landscape boundaries occur along a gradient. The proposed Rule also draws *artificial distinctions* between upland and bottomland, with direct implications for determining jurisdiction (e.g., of ditches). Determination of upland boundaries is challenging, and many landscapes exhibit gradual shifts from bottomland to upland (e.g., ecotones; Decamps and Naiman 1990); this complexity should be acknowledged, not oversimplified. In sum, the proposed Rule's grounding in structural connectivity is weak and its treatment of functional connectivity is non-existent.

The proposed Rule rests on physical, hydrologic connectivity, and ignores chemical and biological connectivity, which is in direct contrast with the intent of the CWA to protect chemical, physical, and biological integrity. The federal agencies propose to use direct hydrologic surface connectivity with other jurisdictional waters as the sole factor determining wetland jurisdiction. Consequently, wetlands that do not abut or have a direct surface water connection with a jurisdictional water would not be protected. Multiple lines of evidence point to the importance of chemical and biological connectivity between wetlands and downstream waters. Non-floodplain wetlands, for example, can be important sources of chemicals and matter (e.g., nutrients, dissolved organic compounds, salts) to downstream waters, which can be detrimental or beneficial depending upon the specific circumstance. Non-floodplain wetlands can also act as chemical sinks, protecting downstream waters by retaining compounds through a suite of physico-chemical processes including denitrification, sedimentation, long-term storage in plant detritus, and ammonia volatilization, among others (Lane et al. 2018). Migratory animals, including migratory birds, transport nutrients, energy, and other organisms between disparate locations, at both local and landscape scales and thus provide functional connectivity between often widely spaced landscape elements, including wetlands and other waterbodies (Subalusky et al. 2009, Bauer and Hoye 2014). Through these movements, biota also prevent inbreeding, escape stressors, locate mates, find food resources, and recolonize habitats, thus contributing to biodiversity and exchanging materials among waterbodies, and serving as critical agents of connectivity and resiliency among streams, wetlands, and downstream waters (Schofield et al. 2018).

The proposed Rule disregards groundwater connectivity. In the most extreme case, the proposed Rule suggests that the simple placement of a small earthen berm would be sufficient to disconnect a floodplain wetland from the otherwise adjacent river, which is an oversimplification that is entirely at odds with our scientific understanding of the relationships between surface water and groundwater. Scientists – including federal scientists – have long known that surface

water and groundwater are a single resource (Winter et al. 1998). Over large scales of space and time, wetlands can have large effects on groundwater recharge (Sinclair 1977, Wood and Sanford 1995, Rains 2011), which in turn can drive flow in streams throughout the region (Winter et al. 1998, Kish et al. 2010). Wetlands and streams are linked by integrated surface-water and groundwater flow systems (Rains et al. 2006), modulating both the local storage of water (Min et al. 2010, McLaughlin et al. 2014, Ali et al. 2017) and the rate at which water flows to downstream waters (Rains et al. 2016). Indeed, given the close connection between surface and groundwater, scientists created the term hyporheic zone, which refers to the boundary where river water and groundwater freely mix in the gravel under and around the river channel (Stanford and Ward 1988). To disregard groundwater connectivity – especially over small distances and short time spans – is to disregard the reality of how the Nation's natural waters function. The fact that the newly proposed Rule includes the language – "The proposed definition specifically clarifies that ''waters of the United States'' do not include features that flow only in response to precipitation; groundwater, including groundwater drained through subsurface drainage systems…" (84 FR 4155) – shows a significant lack of understanding of where and how natural waters accumulate on a landscape. Virtually every "water" is fundamentally dependent on rates of precipitation, accumulation on the surface, and infiltration into the ground. Those accumulated flows are absolutely essential for formations of "waters".

The proposed Rule is not clear. Although the agencies state that the proposed Rule would establish jurisdiction under the CWA in a clearer and more understandable way, the Rule is inconsistent and sets dangerous precedents in fundamental areas such as methods for defining intermittent streams. The agencies suggest using a combination of methods to distinguish perennial and intermittent from ephemeral streams, including field visits and remote tools. One proposal is to require a minimum annual flow duration, such as at least one month per calendar year, which would then exclude vast numbers of intermittent streams that are critical habitat for fish spawning and rearing, among other functions (Colvin et al. 2019). The agencies also propose to remove case-by-case evaluations for non-floodplain wetlands, yet propose case-by-case judgments or their equivalent, in multiple other instances. For example, if the agencies are unsure whether a ditch was constructed in a tributary (in which case it would be considered a WOTUS under the proposed Rule), the agencies would then review the available evidence to determine when the ditch was constructed and the nature of the landscape before and after construction.

The agencies are also unclear about the precise way jurisdictional (i.e., perennial and intermittent) streams will be evaluated. For instance, the agencies suggest using blue-line streams on U.S. Geological Survey (USGS) topographic or National Hydrology Dataset (NHD) maps to identify a potential jurisdictional stream. While the agencies indicate that combining this information with other measures (i.e., stream order, field work) will be important to avoid overestimating flow and erroneously concluding the presence of a jurisdictional tributary, the opposite problem is most likely – that drainage networks have not been mapped at sufficient resolution and thus could grossly *underestimate* streams on the landscape (Meyer and Wallace 2001, Lane et al. 2018). Lang et al. (2012), for example, found that the NHD maps (1:24,000), representing the best available spatial stream data available for the U.S., capture only 66% of stream length compared to maps based on higher resolution LIDAR data. Other advanced tools include a model developed by the US Geological Survey of streamflow permanence for the

Pacific Northwest at a 30-m resolution. The PRObability of Streamflow PERmanence (PROSPER) model could be a substantial improvement over current NHD-derived maps, including predicting intermittent and ephemeral streams (Jaeger et al. 2019). In contrast, using blue-line streams would fail to account for substantial portions of streams across the U.S. landscape.

The proposed Rule seems to leave open the possibility that human activities can lead to removing waters from protection. Under current human-use and water-management schemes, highly vulnerable intermittent and ephemeral streams and rivers are increasingly replacing perennial streams. Perkin et al. (2017) determined a loss of 558 km (21%) of stream length from 1950 to 1980 in the Upper Kansas River Basin, presumably as a result of groundwater pumping accentuated by climate change, with a cumulative loss of 844 km (32%) predicted by 2060. As perennial and intermittent streams shift to ephemeral, they will lose protection under the proposed Rule, setting a dangerous precedent for future loss of federal protection. Under future climate-change scenarios, certain wetlands may also become non-permanent but no less critical for mitigating extreme rain events.

CONCLUDING REMARKS

In summary, the impacts of the proposed Rule will be dire, with the likely loss of protections for thousands of miles of ephemeral streams (Nadeau and Rains 2007, Levick et al. 2008) and over 16 million acres of wetlands in the conterminous U.S. These losses will include particularly vulnerable ecosystems (Creed et al. 2017) including playa lakes, prairie potholes, Carolina and Delmarva Bays, pocosins, and vernal pools (Lane and D'Amico 2016). Because ephemeral streams and non-floodplain wetlands comprise headwaters, the proposed Rule will remove protection for already sensitive ecosystems that provision numerous ecosystem services through watersheds, including biodiversity; delivery of water, sediments, and organic material to downstream waters; filtering nutrients and improving water quality; and flood protection and mitigation (Nadeau and Rains 2007). Headwaters also support endangered species, and both recreationally and commercial fish like salmon, trout, and herring (Colvin et al. 2019). A recent exploratory analysis by Saint Mary's University of Minnesota (SMUM 2019) predicts severe losses of wetland functions under the proposed Rule, with impacts to wetlands in arid and semi-arid regions particularly high. For instance, the Cimarron River Watershed in northeastern New Mexico is projected to lose between 18 and 69% of its wetlands under the proposed Rule.

As members of the previous SAB panel that reviewed the Connectivity Report and the 2015 CWR, we are intimately familiar with the science supporting the 2015 CWR and the critical role played by the CWA in protecting our Nation's waters. We strongly oppose the proposed Rule, which we find to be inconsistent with science, based upon flawed logic, and too ambiguous for decision-making.

Sincerely,

S. Mažeika P. Sullivan[1], Mark C. Rains[2], Amanda D. Rodewald[3,4], Genevieve Ali[5], Emma Rosi[6], Kurt D. Fausch[7], Jennifer L. Tank[8], Robert P. Brooks[9], Michael N. Gooseff[10], M. Siobhan Fennessy[11], Mark T. Murphy[12], Judy L. Meyer[13], J. David Allan[14]

AFFILIATIONS:
[1]Schiermeier Olentangy River Wetland Research Park, School of Environment & Natural Resources, The Ohio State University, Columbus, Ohio 43202 USA

[2]School of Geosciences, University of South Florida, Tampa, FL 33620 USA

[3]Cornell Lab of Ornithology, Cornell University, Ithaca, NY 14850 USA

[4]Department of Natural Resources, Cornell University, Ithaca, NY 14850 USA

[5]School of Environmental Sciences, University of Guelph, Guelph, Ontario, N1G 2W1 Canada

[6]Cary Institute of Ecosystem Studies, Millbrook, NY, 12545 USA

[7]Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, CO 80523 USA

[8]Department of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556 USA

[9]Department of Geography, Pennsylvania State University, University Park, PA 16802 USA

[10]Institute of Arctic and Alpine Research and Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder CO 80303 USA

[11]Biology Department and Environmental Studies Program, Kenyon College, Gambier, OH 43022

[12]Hassayampa Associates, Tucson Arizona, 85704 USA

[13]Odum School of Ecology, University of Georgia, Athens GA 30602 USA

[14]School for Environment and Sustainability, University of Michigan, Ann Arbor, MI 48109 USA

References

Ali, G., A. Haque, N. B. Basu, P. Badiou, and H. Wilson. 2017. Groundwater-driven wetland-stream connectivity in the Prairie Pothole Region: inferences based on electrical conductivity data. Wetlands **37**:773-785.

Ali, G., C. Oswald, C. Spence, and C. Wellen. 2018. The T-TEL method for assessing water, sediment, and chemical connectivity. Water Resources Research **54**:634-662.

Amoros, C., and G. Bornette. 2002. Connectivity and biocomplexity in waterbodies of riverine floodplains. Freshwater Biology **47**:761-776.

Bauer, S., and B. J. Hoye. 2014. Migratory animals couple biodiversity and ecosystem functioning worldwide. Science **344**:54-+.

Cohen, M. J., I. F. Creed, L. Alexander, N. B. Basu, A. J. K. Calhoun, C. Craft, E. D'Amico, E. DeKeyser, L. Fowler, H. E. Golden, J. W. Jawitz, P. Kalla, L. K. Kirkman, C. R. Lane, M. Lang, S. G. Leibowitz, D. B. Lewis, J. Marton, D. L. McLaughlin, D. M. Mushet, H. Raanan-Kiperwas, M. C. Rains, L. Smith, and S. C. Walls. 2016. Do geographically isolated wetlands influence landscape functions? Proceedings of the National Academy of Sciences of the United States of America **113**:1978-1986.

Colvin, S. A. R., S. M. P. Sullivan, P. D. Shirey, R. W. Colvin, K. O. Winemiller, R. M. Hughes, K. D. Fausch, D. M. Infante, J. D. Olden, K. R. Bestgen, R. J. Danehy, and L. Eby. 2019. Headwater streams and wetlands are critical for sustaining fish, fisheries, and ecosystem services. Fisheries:10.1002/fsh.10229.

Creed, I. F., C. R. Lane, J. N. Serran, L. C. Alexander, N. B. Basu, A. J. K. Calhoun, J. R. Christensen, M. J. Cohen, C. Craft, E. D'Amico, E. DeKeyser, L. Fowler, H. E. Golden, J. W. Jawitz, P. Kalla, L. K. Kirkman, M. Lang, S. G. Leibowitz, D. B. Lewis, J. Marton, D. L. McLaughlin, H. Raanan-Kiperwas, M. C. Rains, K. C. Rains, and L. Smith. 2017. Enhancing protection for vulnerable waters. Nature Geoscience **10**:809-815.

Decamps, H., and R. J. Naiman. 1990. Towards an ecotone perspective. Ecology and Management of Aquatic-Terrestrial Ecotones **4**:1-5.

Evenson, G. R., H. E. Golden, C. R. Lane, and E. D'Amico. 2015. Geographically isolated wetlands and watershed hydrology: A modified model analysis. Journal of Hydrology **529**:240-256.

Fausch, K. D., C. E. Torgersen, C. V. Baxter, and H. W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. Bioscience **52**:483-498.

Fritz, K. M., K. A. Schofield, L. C. Alexander, M. G. McManus, H. E. Golden, C. R. Lane, W. G. Kepner, S. D. LeDuc, J. E. DeMeester, and A. I. Pollard. 2018. Physical and chemical connectivity of streams and riparian wetlands to downstream waters: a synthesis. Journal of the American Water Resources Association **54**:323-345.

Gorelick, S. M., and C. M. Zheng. 2015. Global change and the groundwater management challenge. Water Resources Research **51**:3031-3051.

Harvey, J., J. Gomez-Velez, N. Schmadel, D. Scott, E. Boyer, R. Alexander, K. Eng, A. Kettner, C. Konrad, R. Moore, J. Pizzuto, G. Schwarz, C. Soulsby, and J. Choi. 2018. How hydrologic connectivity regulates water quality in river corridors. Journal of the American Water Resources Association. https://doi.org/10.1111/1752-1688.12691.

Jaeger, K. L., R. Sando, R. R. McShane, J. B. Dunham, D. P. Hockman-Wert, K. E. Kaiser, K. Hafen, J. C. Risley, and K. W. Blasch. 2019. Probability of Streamflow Permanence

Model (PROSPER): A spatially continuous model of annual streamflow permanence throughout the Pacific Northwest. Journal of Hydrology **2**:100005.
Kish, G. R., C. E. Stringer, M. T. Stewart, M. C. Rains, and A. E. Torres. 2010. A geochemical mass-balance method for base-flow separation, Upper Hillsborough River Watershed, west-central Florida, 2003-2005 and 2009. Scientific Investigations Report 2010–5092. U.S. Geological Survey, Reston, Virginia, USA.
Lane, C. R., and E. D'Amico. 2016. Identification of putative geographically isolated wetlands of the conterminous United States. Journal of the American Water Resources Association **52**:705-722.
Lane, C. R., S. G. Leibowitz, B. C. Autrey, S. D. LeDuc, and L. C. Alexander. 2018. Hydrological, physical, and chemical functions and connectivity of non-floodplain wetlands to downstream waters: a review. Journal of the American Water Resources Association **54**:346-371.
Lang, M., O. McDonough, G. McCarty, R. Oesterling, and B. Wilen. 2012. Enhanced detection of wetland-stream connectivity using LiDAR. Wetlands **32**:461-473.
Leibowitz, S. G., P. J. Wigington, K. A. Schofield, L. C. Alexander, M. K. Vanderhoof, and H. E. Golden. 2018. Connectivity of streams and wetlands to downstream waters: an integrated systems framework. Journal of the American Water Resources Association **54**:298-322.
Levick, L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The ecological and hydrological significance of ephemeral and intermittent streams in the arid and semi-arid American Southwest. EPA/600/R-08/134, ARS/233046. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, Washington, D.C., USA.
Marton, J. M., I. F. Creed, D. B. Lewis, C. R. Lane, N. B. Basu, M. J. Cohen, and C. B. Craft. 2015. Geographically isolated wetlands are important biogeochemical reactors on the landscape. Bioscience **65**:408-418.
McLaughlin, D. L., D. A. Kaplan, and M. J. Cohen. 2014. A significant nexus: Geographically isolated wetlands influence landscape hydrology. Water Resources Research **50**:7153-7166.
Meyer, J. L., and J. B. Wallace. 2001. Lost linkages and lotic ecology: Rediscovering small streams. Pages 295-317 *in* N. Huntly, J, and S. Levin, editors. Ecology: Achievement and challenge. Blackwell Scientific, Oxford, UK.
Min, J. H., D. B. Perkins, and J. W. Jawitz. 2010. Wetland-Groundwater Interactions in Subtropical Depressional Wetlands. Wetlands **30**:997-1006.
Nadeau, T. L., and M. C. Rains. 2007. Hydrological connectivity between headwater streams and downstream waters: How science can inform policy. Journal of the American Water Resources Association **43**:118-133.
Perkin, J. S., K. B. Gido, J. A. Falke, K. D. Fausch, H. Crockett, E. R. Johnson, and J. Sanderson. 2017. Groundwater declines are linked to changes in Great Plains stream fish assemblages. Proceedings of the National Academy of Sciences of the United States of America **114**:7373-7378.
Petts, G. E., and C. Amoros. 1996. The fluvial hydrosystem. Pages 1-12 *in* G. E. Petts and C. Amoros, editors. Fluvial hydrosystems. Chapman & Hall, London, United Kingdom.

Rains, M. C. 2011. Water Sources and Hydrodynamics of Closed-Basin Depressions, Cook Inlet Region, Alaska. Wetlands **31**:377-387.

Rains, M. C., G. E. Fogg, T. Harter, R. A. Dahlgren, and R. J. Williamson. 2006. The role of perched aquifers in hydrological connectivity and biogeochemical processes in vernal pool landscapes, Central Valley, California. Hydrological Processes **20**:1157-1175.

Rains, M. C., S. G. Leibowitz, M. J. Cohen, I. F. Creed, H. E. Golden, J. W. Jawitz, P. Kalla, C. R. Lane, M. W. Lang, and D. L. McLaughlin. 2016. Geographically isolated wetlands are part of the hydrological landscape. Hydrological Processes **30**:153-160.

Rinderera, M., G. Ali, and L. G. Larsen. 2018. Assessing structural, functional and effective hydrologic connectivity with brain neuroscience methods: State-of-the-art and research directions. Earth-Science Reviews **178**:29-47.

Schofield, K. A., L. C. Alexander, C. E. Ridley, M. K. Vanderhoof, K. M. Fritz, B. C. Autrey, J. E. DeMeester, W. G. Kepner, C. R. Lane, S. G. Leibowitz, and A. I. Pollard. 2018. Biota connect aquatic habitats throughout freshwater ecosystem mosaics. Journal of the American Water Resources Association **54**:372-399.

Sinclair, W. C. 1977. Experimental study of artificial recharge possibilities in Northwest Hillsborough County, Florida. Water-Resources Investigations 77–13. US Geological Survey, Reston, Virginia, USA.

SMUM. 2019. Modeling federally protected waters and wetlands. Saint Mary's University of Minnesota, GeoSpatial Services, Winona, MN. http://smumn.maps.arcgis.com/apps/Cascade/index.html?appid=f3de6b30c0454c15ac9d3d881f18ae33

Stanford, J. A., and J. V. Ward. 1988. The hyporheic habitat of river ecosystems. Nature **335**:64-66.

Subalusky, A. L., L. A. Fitzgerald, and L. L. Smith. 2009. Ontogenetic niche shifts in the American Alligator establish functional connectivity between aquatic systems. Biological Conservation **142**:1507-1514.

Tagwireyi, P., S. M. P. Sullivan, and K. G. Zhao. 2017. Associations between riverine landscape patches and internal and external environmental determinants are scale dependent: evidence from the Scioto River, USA. Fundamental and Applied Limnology **190**:235-249.

USEPA. 2014. Letter to Gina McCarthy. October 17, 2014. SAB Review of the Draft EPA Report Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence. U.S. Environmental Protection Agency, Washington D.C., USA.

USEPA. 2015. Connectivity of streams and wetlands to downstream waters: a review and synthesis of the scientific evidence technical report. EPA/600/R-14/475F. US Environmental Protection Agency, Washington, D.C., USA.

Wiens. 2002. Riverine landscapes: taking landscape ecology into the water. Freshwater Biology **47**:777-798.

Winter, T. C., J. W. Harvey, O. L. Franke, and W. M. Alley. 1998. Ground water and surface water: a single resource. Circular 1139. U.S. Geological Survey, Reston, Virginia, USA.

Wood, W. W., and W. E. Sanford. 1995. Chemical and isotopic methods for quantifying groundwater recharge in a regional, semiarid environment. Ground Water **33**:458-468.