To: EPA

From: James Perry, President of the Society of Wetland Scientists (SWS)

Re: Subject: EPA-HQ-OW-2011-0880. **SWS Comment on the EPA proposed rule** on waters of the US, compiled by SWS members Joy Zedler, Daniel Larkin, and Carter Johnson

SWS is an international membership organization of more than 3,000 wetland professionals dedicated to fostering sound wetland science, education, and management.

SWS supports the EPA proposed rule on waters of the US as follows:

• **The proposed rule is science-based**, following EPA's review of over 1,000 peer-reviewed papers on the physical, chemical, and biological connections by which streams, wetlands, and open-waters affect downstream waters such as rivers, lakes, and oceans. The review is comprehensive, clear, technically accurate, and it summarizes solid science. The proposed rule correctly addresses the provision of clean water, which is a well-known function of wetlands. Here, we emphasize and expand on the following topics:

A. The quality of downstream waters depends on materials that are (or are not) discharged upstream in the watershed and carried by streams to wetlands that can remove materials and cleanse the water.
B. The system of connected streams and wetlands includes wetlands that perform in aggregate, both synergistically and cumulatively. We illustrate this for the Prairie Pothole Region (PPR).
C. Because water quality is degraded during and after flooding, SWS supports the need to protect wetlands to reduce flood risk.

A. **The quality of downstream waters depends on materials that are (or are not) discharged upstream in the watershed and carried by streams to wetlands that can remove materials and clean the water.**

- *Isolated wetlands* can improve water elsewhere in a landscape by trapping and retaining surface or groundwater discharges that would otherwise carry pollutants downstream.

- Non-isolated streams and wetlands are often *connected as a system*, either via surface water or groundwater. Wetlands that are connected improve water quality by performing *complementarily* along the water's flow path, with sequential contributions to the removal of solid and dissolved materials depending on the quality (e.g., particle size and weight) of the materials and the condition of the wetland (frozen or thawed, nutrient starved or eutrophic, deep or shallow, etc.). *The arrangement of wetlands on the landscape (size, density, position, etc.) influences water quality variables and flooding.* *The system is complex* and modelers now see the need to consider wetlands in aggregate (Zhang et al. 2012).

Quoting Zhang et al (2012) further:

"Understanding the implications of wetlands on downstream lake phosphorus concentration requires detailed landscape and hydrological information about the catchments of individual wetland units (Tompkins et al. 1997)."

"When inflow phosphorus concentration of a wetland is very high, it is likely that the wetland's effect on phosphorus retention exceeds its effect on consuming water and thus makes the phosphorus concentration lower at the outlet of wetland."

- *Larger areas* of wetland in a watershed *remove larger amounts of materials*. Johnston et al. (1990) found a threshold effect—reduced water quality where watershed area dropped below10%. This non-linear relationship indicates a synergism, not a simple addition.

- Water quality services are *not just a linear/additive function* of wetland area. High-quality water requires large wetland complexes *and* small wetlands dispersed across watersheds. Landscape heterogeneity and wide scattering of wetlands across the landscape are positive predictors of water quality (Moreno-Mateos et al. 2008). 'Scattered and numerous wetlands are better than few and aggregated ones, because within the whole catchment they will increase landscape complexity (patch density and heterogeneity) and accordingly reduce the amount of TDS in water" (ibid.; TDS = total dissolved solids).

- Detenbeck et al. (1993) showed that, for 33 watersheds near Minneapolis, downstream lakes had higher water quality where there were upstream wetlands in *close proximity* to the downstream lake. Similarly, Newbold (2005) found that "Targeted site selection in four small watersheds in the Central Valley resulted in predicted levels of nitrogen attenuation two to eight times greater than that from maximizing wetland area without consideration of the location of the restoration sites." This modeling study indicated high sensitivity to wetland *distribution*, not just wetland *area*.

B. **The system of connected streams and wetlands includes wetlands that perform in aggregate** within watersheds and/or landscapes (the latter being a more appropriate concept for flat topography, as in the prairie pothole region). Materials added to small streams and/or small wetlands, in aggregate, have cumulative effects downstream. The concept of performing in aggregate pertains to spatial and temporal frameworks. Small amounts of material added to many waters upstream adds up to a large loading downstream, as do small amounts of material added frequently over time. The early understanding of cumulative impacts and functioning in aggregate has withstood the test of rigorous research.

- Wetlands in aggregate can function *synergistically* (i.e., the whole is greater than the sum of the parts). For example, vernal pools support "meta-populations" of plants and animals. Meta-populations are sustained even if one more more sub-portions decreases; the probability of at least one sub-population persisting is greater where propagules can easily move from one pool to another. Several pools in close proximity can sustain populations (e.g., an annual plant or amphibian) better than fewer pools located at greater distances from one another.

- The concept that *wetlands perform in aggregate* over space and time was embodied in early predictions that the effects of losing multiple wetlands or that degradation across many wetlands would need to be considered in a *cumulative impact assessment* (Brinson 1988, Hemon and Benoit 1988, O'Brien 1988, Preston and Bedford 1988, Siegel 1988, and Winter 1988). Their advice 25 years ago still holds: functions of wetlands should not be viewed independently; the cumulative function of all wetlands in a watershed may differ from simply adding the functions of individual wetlands.

Quotes from Johnston et al. 1990:

"The relationship between basin storage (as percentage of basin area in wetlands and lakes) and relative flood flow is non-linear in the empirical models developed by Jacques & Lorenz (1988), so that our data yielded a critical threshold at about 10%. Small wetland losses in watersheds with < 10% wetlands could have a major effect on flood flows. A similar threshold was found for wetlands in Wisconsin watersheds by Novitzki (1979).

"Cumulative impact assessment differs substantially from the approach used by existing wetland evaluation systems (Reppert et al. 1979; U.S. Army Corps of Engineers 1980; USFWS 1980; Adamus 1983) because it evaluates the collective function of a group of wetlands, rather than the contribution of an individual wetland.

"Our results indicate the importance of considering wetland position in the landscape when evaluating cumulative function. All wetlands in a watershed do not behave alike with regard to water quality function, which may explain why previous attempts to relate percent wetland to drainage basin water quality have generally been unsuccessful (Whigham & Chitterling 1988).

"Therefore, the position of wetlands in the watershed appears to have a substantial effect on water quality, particularly with regard to sediment and nutrients."

Additional relevant points by wetland scientists:

"Understanding the relationship between *wetland cover in the watershed* and coastal marsh *water quality* is important not only for the purpose of predicting natural variation in water quality, but also for understanding the implications of wetland loss that often occurs as a result of human development (Wolter and others 2006). Like Johnston and others (1990), we found wetland cover to be a significant factor determining COND levels [specific conductivity]. Wetlands have the ability to filter dissolved ions and nutrients in surface runoff (Hemond and Benoit 1988; Johnston et al. 1990) and can therefore help reduce ionic concentrations. As expected, we also found that *greater wetland cover is* related to lower levels of TNN in marshes at the watershed outflow. This is consistent with a large body of literature that outlines the importance of wetlands in the nitrogen cycle." (DeCatanzaro et al. 2009) (TNN = total nitrate nitrogen)

"Regional landscape setting influences local wetland relationships with TP and color through cross-scale interactions, and lake TP and color are controlled by *both local-scale wetland extent and regional-scale landscape variables*." (Fergus et al. 2011)

Complex effects of upstream wetlands on downstream waters:

The following *Prairie Pothole Region* (PPR) case study illustrates one clear finding from the EPA/COE science review and proposed rule, namely, there is great complexity in the ways that upstream wetlands influence downstream waters. The complexity of processes involved and their highly variable influence in space and time make it difficult to assign level or degree of connectivity to any given wetland, wetland complex, or even watershed. This difficulty in turn makes the regulatory mission challenging.

- *Four main functions of wetlands in the PPR produce interconnectedness: fill and spill; recharge/discharge; biodiversity inoculum; groundwater flux.* As detailed below, three of these functional connections (fill-spill; recharge-discharge; biodiversity inoculum) between pothole wetlands and downstream waters are supported by solid, peer-reviewed, science. All functional pothole wetlands fill with water and contribute biodiversity inoculum; a large percentage of pothole wetlands spill water that often joins downstream waters; virtually all functional pothole wetland complexes contribute to recharge and discharge that lengthens the hydroperiod of more permanent wetlands and increases the chance that surface water spills and enters downstream waters; movement of water from pothole wetlands to deep groundwater that then enters downstream surface waters is likely to occur but is difficult to determine from field studies. Parsing out which pothole wetland provides each of the four functions and documenting how often each occurs is not tractable from a research perspective. The few uncertainties should not be the enemy of the far more numerous certainties. *The dominant message from the EPA science review and this SWS assessment is that connections between pothole wetlands and downstream waters are strong and undeniable.*

1. *Fill and spill*. Perhaps the clearest hydrological connection between prairie wetlands and downstream waters is their capture and storage of rainstorm and snow pack runoff (*fill function*). Calculations presented in the science review show that substantial amounts of water can be held back from streams and rivers by pothole wetlands, thus reducing flood magnitude and frequency. In a large proportion of prairie wetlands, however, especially in easterly parts of the prairie pothole region (PPR) with moderate to high rainfall (Millett et al. 2009), wetlands cannot capture and hold all water inputs. In these areas, integrated drainage networks have formed over time from spilled water (spill function), and connectivity between wetland basins and downstream waters is direct and observable. While spilling is more likely and voluminous in wetter regions, it can occur in drier, more westerly PPR regions during periods of deluge such as those observed in the 1990s (Winter and Rosenberry 1998). Most of the ten wetlands at Orchid Meadows, a long-studied wetland complex in eastern South Dakota (central PPR), overflowed frequently and contributed substantial volumes of water via channel outflow to a deep, recreational lake (Johnson et al. 2004, van der Kamp and Hayashi 2009). *Both fill and spill functions occur in prairie wetlands across the PPR*; the spill function is more evident in the integrated drainage network of the central and eastern PPR.

2. Recharge/discharge. A second well-studied process identified in the science review, termed recharge/discharge, connects members of a wetland complex to each other hydrologically. *However, the physical connection between less permanent pothole wetlands and downstream waters was not identified or discussed in the EPA science review.* In the PPR, topographically higher wetlands (usually those classified as temporary or seasonal in permanence category) recharge shallow groundwater that discharges into lower semi-permanent wetlands. This topographically driven, regional-local flow system functions when water percolates through fracture cracks in the glacial till beneath wetland basins. The permeability of the tills depends on the degree of fracturing that is best developed in surface soils. The amount of water that discharges from higher wetlands into lower ones can be sufficient to lengthen the hydroperiod of receiving wetlands and to shift them from seasonal to semi-permanent. The water budgets of wetlands in complexes do not balance in mathematical models without accounting for the recharge function (Johnson et al. 2010). In this way, investigators have found a link between the more ephemeral wetlands, often occurring in higher landscape positions, and downstream water. More specifically, recharge maintains deeper semi-permanent

wetlands increasing the frequency and volume of spilling into downstream waters after snow melt and rain storms. *This physical connection between less permanent pothole wetlands and downstream waters is a useful addition to the EPA science review.*

3. Groundwater flux**.** Major questions raised in the EPA science review were: How connected are pothole wetlands to deeper groundwater? Do pothole wetlands directly recharge downstream streams, river, and lakes via deeper ground water? *It is well established that water movement among wetlands is part of the shallow groundwater system* (van der Kamp and Hayashi 2009). Deeper tills, however, generally have low hydraulic conductivity allowing only very slow movement of water. But there are exceptions. In the more rugged parts of the PPR, where most functional wetlands remain, the till underlying or adjacent to wetlands includes materials varying in coarseness and permeability, ranging from cobble and gravel through sand to heavy clay. The sands and gravels occur as extensive sheets, long narrow buried-valley deposits, and many small deposits of local extent (van der Kamp and Hayashi 2009). The deposits can function as aquifers that distribute recharge water from "leaky" wetlands to deeper groundwater, and then possibly to down gradient surface waters. Because aquifers are encountered frequently when coring, it is likely that some wetlands do feed surface waters through deeper groundwater pathways. Research into the complex "black box" of groundwater movement in the glacial tills in the PPR has yet to prove and quantify the occurrence of such flow paths. However, known passage of salts from wetlands into deep groundwater storage has been determined (van der Kamp and Hayashi 2009).

4. Biodiversity inoculum. The EPA science review lays out a clear case that pothole wetlands contribute biodiversity inoculum to downstream waters. Some forms of the inoculum, such as seeds and whole plants, are transported directly by water that spills to downstream streams, rivers, and lakes. Other organisms, such as amphibians that live and reproduce in pothole wetlands, depend on spillage flow pathways and other surface water sources to disperse and recolonize new sites downslope. Still others, such as migratory waterfowl that breed in pothole wetlands, complete their breeding cycle in late summer by moving to more permanent downstream waters. A countless number of species from single celled organisms to vertebrates move from pothole wetlands to downstream waters in a myriad of ways in time and space to complete their life cycles and to colonize new sites as a means to maintain and expand their populations. Pothole wetlands play a major role in the ability of plants, animals, and microbial communities to remain functional and diverse in glaciated prairie landscapes.

C. **Because water quality is degraded during and after flooding, SWS supports the need to protect wetlands to reduce flood risk,** which will be increasingly important during future climates with more frequent, more extreme streamflow events. Here are relevant sections of recent scientific publications.

• Floods, like water quality, relate to the built environment. A study from Texas, which consistently has the nation's greatest impacts of flooding, concerned 423 flood events from 1997 to 2001 and identified impacts of several measures, including wetland alteration, impervious surfaces, and dams. Their results support the important role of naturally occurring wetlands in mitigating flood damage (Brody and Zahran 2008).

• It is conventional wisdom that losing wetlands increases flood risk. However, *it is novel to quantify cumulative impacts at a watershed scale*: Ahmed (2014) estimated a 4% increase in the 100-year flood as a result losing non-*provincially significant wetlands* (6% of basin area; PSW are *provincially significant wetlands recognized by Ontario*)… Adding non-PSWs (combined total = 15% of basin area) and assuming similar hydrological functions regardless policy-related class, peak flood attenuation was estimated to improve 9-10%. Removal of non-PSWs will increase the value of the 1-day flow by up to 50%.

• "…federal permits issued to alter a naturally occurring wetland exacerbate flooding events in coastal watersheds along the Gulf of Mexico… importance of our findings for planners and policy makers interested in reducing the adverse impacts of coastal flooding is that flood events are regulated not solely by the effect of permit counts, but by the type of permit granted. First, as expected, IP [individual permits] significantly increase flooding because they signify development projects requiring large amounts of wetland (>0.5 acres) to be disrupted. These projects usually involve the addition of impervious surfaces… Decision makers should carefully monitor the number and location of IP granted within a watershed to ensure the hydrological system remains relatively intact… Second, while we expect large development projects and associated impervious surfaces to increase the rate of flooding, the even stronger positive effect of GP [general permits] is somewhat surprising. This result indicates that *relatively small-scale wetland alteration such as with the case of residential development have more serious ''cumulative impacts'' on flooding over time.* GP may be indicative of sprawling development patterns where each individual project may not cause a severe impact, but the total sum of all small disruptions to a watershed unit results in loss of hydrological function and resulting increased flood events. This '**death by a thousand cuts**' phenomenon should be a primary concern for environmental and hazard mitigation planners. *Officials need to **steer** their focus away from site-based review and incremental decision making toward the watershed level where cumulative impacts are more easily detected.* (Brody et al. 2007a)

Wetland loss is the primary driver of increased flood risk. "Although the total amount of impervious surface in an area is often cited as the culprit for increased flooding and associated property damage, these may result more from exactly where these surfaces are, and how they affect the natural environment… by separating the variable measuring wetland development from the variable measuring impervious surface, we eliminate from the latter from what may be its most important adverse hydrological impact: loss of wetlands. We noticed the same trends in related studies of floods at both the local jurisdiction scale and the watershed scale (Brody, Highfield, et al., 2007; Brody et al. 2008).

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