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Effectiveness of Wetlands to Reduce Nutrient Levels

In the past several years Ohio has experienced harmful algal blooms and other impacts caused by excessive nutrient levels in a number of our waters including many streams, the Ohio River, Lake Erie and numerous smaller lakes. The restoration or construction of wetland areas have been proposed as one means of helping to reduce elevated nutrient levels in the Western Lake Erie Basin and other geographies in the state. Wetlands store water, nutrients and sediment on both short and long-term time scales (Kadlec and Wallace, 2008; Mitsch and Gosselink, 2007; Nichols, 1983; Reddy and DeLaune, 2008; Reddy et al., 1998). However, it is important to understand how effective wetlands are at improving water quality by reducing the levels of different types of nutrients, what factors lead to large reductions or likewise can negate the ability to process or hold nutrients.

<u>Generalized removal rates reported</u>:

Nitrogen:

- Total nitrogen: 37% (95% CI of 29-44%) (Land et al 2016); 40-55% (Vymazal 2007)
- Nitrate: 27-51% (Tomer et al., 2012; Crumpton et al., 2006; and Dale et al., 2010)

Phosphorus:

- Median TP: 46%, (95% CI of 37-55%) (Land et al 2016)

In general, wetlands have been shown to be an effective means of improving water quality through the capture of sediment and reduction of nutrient levels in outflows although long-term (>20 years) performance is not well documented yet in the scientific literature (Land et al 2016). Land et al (2016) found that "On average, created and restored wetlands significantly reduce the transport of Total Nitrogen (TN) and Total Phosphorus (TP) in treated wastewater and urban and agricultural runoff, and may thus be effective in efforts to counteract eutrophication." It is common to find at least 25%, and even over 50%, removal reported (Kadlec et al., 2010; R. Kröger et al., 2013; Moreno-Mateos et al., 2010; Novak et al., 2004; Reddy et al., 1999) in precipitation-driven systems. However, there are some differences in ability of wetlands to reduce outflow levels of TN, Nitrate, and TP and the various bioavailable forms of each such as Total Kjehldahl nitrogen (TKN) and dissolved or soluble reactive phosphorus (DRP & SRP).

<u>Nitrogen</u>: Wetlands have been demonstrated to be highly effective in reducing both TN and nitrate levels through the process of denitrification. Land et al (2016) in a meta-analysis found the median removal rate among studies for TN was 37% (95% CI of 29-44%) and Vymazal (2007) determined that "Removal of total nitrogen in studied types of constructed wetlands varied between 40 and 55%". Likewise, a similar range of nitrate removals have been documented. Mitsch et al (2005) found a nitrate removal of 22-25% while other researchers and reviewers suggest that wetlands would remove 27–51% on the incoming nitrate load (Tomer et al., 2012; Crumpton et al., 2006; and Dale et al., 2010). In summary, wetlands can reduce N levels by up to about half.

<u>Phosphorus</u>: Reduction of the various forms of phosphorus in wetland outflows appears to be more variable among wetland types and environmental conditions. Land et al (2016) found the median TP removal among project outcomes was 46%, (95% CI of 37-55%). Conversely, Kovacic et al. (2000) monitored three constructed wetlands receiving cropland tile drainage in Illinois and found that overall removal efficiencies were 22% for DRP but only 2% for total P. Natural floodplain wetlands that connect

to rivers during high flow events can trap large amounts of sediment and associated particulate P (Noe & Hupp, 2005). Wetlands along rivers that receive a portion of the flow from upstream watershed areas (not just a single or small number of fields) have also been shown to reduce Dissolved Reactive Phosphorus (DRP) by 61% during the growing season (Noe and Hupp 2007, 2009) although it should be noted that the highest nutrient inflows often occur outside of the growing season.

<u>Loading rates and other factors</u>: The range of wetland treatment effectiveness reported has often been linked to the nutrient load (Land et al., 2016; Novak et al., 2007), fluctuation of inflows (Tanner & Kadlec 2013), environmental factors such as temperature and vegetation (Kadlec 2011), and physical characteristics of the wetland with some wetlands being minimally effective (Jordan et al 2003) to others that are highly effective (Rozema et al 2016). These results offer important clues as to the most important considerations for the restoration, construction, and management of either natural or constructed wetlands for improvement of water quality. In many instances the removal efficiency of nutrients was correlated with inlet nutrient concentration, nutrient and water loading rate, water retention time, and wetland area (Land et al., 2016; Maynard et al., 2009; Novak et al., 2007; Tanner et al., 2005)

Under different conditions wetlands either retain or release nutrients (Kroger et al., 2013; Kovacic et al., 2000). Restoration and management of natural wetlands or design of constructed wetlands that focuses on creating known favorable retention processes is critical and can be optimized for the types of nutrient retention that is desired (Tanner and Kadlec, 2013; Strand and Weisner 2013). As one example, forested wetlands are highly effective at sequestering P but trees seem to lessen the effectiveness of N removal while the presence of soft, emergent soft-tissue vegetation results in higher N reduction efficiency (Kadlec 2011). Constructed wetlands projects have additional considerations necessary to their design/maintenance to retain nutrients and these include:

- Variations in constructed wetland P removal are likely related to temporal variability in seasonal hydraulic loading patterns, establishment and maturation of wetland vegetation, and the P sorption characteristics of soils and organic matter (King et al 2015)
- Removal effectiveness only applies to the area captured and treated, not the whole watershed
- Must ensure adequate design (e.g., stay within hydrologic loading rate limits; challenge of treating tile drainage; limits to what can be treated due to topography)
- There is less information on wetland performance in treating subsurface drainage than surface drainage (King et al 2005; Tanner et al., 2005)

Utilizing advantageous watershed positioning, creating optimal retention factors, and creating or restoring a wetland that is adequately sized (Iowa Department of Agriculture 2009; Schumacher et al 2015) to effectively treat the volume of water and nutrients that it receives can result in very significant watershed scale nutrient reductions. Tomer et al (2013) determined that in some instances wetlands located using LiDAR data could provide up to a 13% reduction in watershed nitrate loss while only directly servicing 30% of the watershed. In Ohio, Schumacher et al (2015) also utilized LiDAR data and other modeling techniques in three small watersheds (including Upper Riley Creek in NW Ohio) to determine that strategically placed and constructed wetlands could reduce nitrate levels by 40% and TP by 45% while only utilizing 1.75% of the watershed for nutrient reduction wetlands.

Moreover, in a comparison of cover crops, wetlands, and two-stage ditches as a means of reducing nutrient levels Roley et al (2016) found that wetlands were the most cost-effective practice (in $ kg N−1 removed) over both 10 and 50-year time horizons at least for N reduction. Therefore, based on the information summarized in this document The Nature Conservancy in Ohio believes that wetland restoration or creation undertaken strategically and extensively within watersheds, with an eye toward creating optimal retention factors, and sited in cooperation with landowners and partners can provide a significant part of the needed nutrient reduction in the Lake Erie and Ohio River Basins.

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