

## Using Constructed Treatment Wetlands for Nutrient Load Reduction to Estuaries: An Illustrative Example from Virginia

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Constructed wetlands, commonly accepted as a “Best Management Practice” for amelioration of nonpoint source loading, are seen as the cost-effective technology applicable to the landscape scale necessary to reverse estuarine hypoxia attributable to agricultural nitrogen pollution. Because wetlands are shallow (30-60 cm) and with hydraulic residence times of days to weeks, and pollutant removal rates vary with the pollutant, land area requirements per unit flow can range from  $\sim 11\text{-}106\text{ m}^2/\text{m}^3\cdot\text{d}$  ( $\sim 10\text{-}100$  acres/mgd). Establishing load restrictions to surface waters through TMDLs poses an opportunity to use treatment wetlands to provide cost-effective load reductions, where land is available.

As a mass load reduction technology, treatment wetlands are robust, easily maintained, and self-sustaining when hydraulic and nutrient loading is maintained within acceptable envelopes of performance. High rates of flow through a wetland can achieve significant mass reductions. Mass loads decrease relatively quickly through the wetland flow path and gradually level out as concentrations begin to approach the background. Wetland efficiency diminishes with diminishing mass loading, and suggests that a wetland could be configured to an optimum area based upon the rate of mass removal, related to hydraulic loading rate.

The Park 500 Natural Treatment System (NTS) operated by PMUSA near Richmond VA provides a recent constructed wetland case history with features that provide a relevant basis for discussion of this concept. Constructed in 2008 as a voluntary method of improving the quality of the facility's wastewater discharge, Park 500 consists of six emergent marshes totaling 17 ha (43 ac) and receiving 4500 m<sup>3</sup>/d (1.2 mgd) of tobacco product process wastewater. Flow is distributed across two flowpaths (E, W) and through three cells in series. The NTS is designed to remove phosphorus and nitrogen mass loads in discharges to the James River.

Inlet phosphorus concentrations averaging 0.35 mg/L are reduced to outlet concentrations of  $\sim 0.08$  mg/L, and mass removal rates decrease from over 4 g/m<sup>2</sup>/yr in the inlet cells to 2.5 g/m<sup>2</sup>/yr in the terminal cells. Conceptually, to achieve greater phosphorus concentration reductions at Park 500, the wetland area could be increased, or the hydraulic loading rates reduced. To emphasize more efficient mass removal, the given footprint of land occupied by the wetlands, conceptually 2x more mass could be removed with a three-fold increase in flow. By distributing the highest strength inflow to all cells, each cell would receive the greatest mass loading possible and achieve the greatest mass removals in proportion to mass loading. Nitrate reductions are even more pronounced in the wetland and show the same general relationship. Park 500 provides a pertinent example of the expected performance of a temperate zone wetland that demonstrates the versatility of wetland configurations to emphasize nutrient mass removal, as appropriate for TMDL compliance or concentration reduction.

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