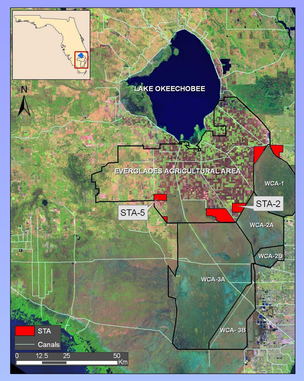
Water and Sediment Phosphorus Gradients in Everglades Stormwater Treatment Areas

Scott Jackson[1], Thomas A. DeBusk[1], Forrest E. Dierberg[1], and Delia Ivanoff [2]

[1] DB Environmental, Inc., Rockledge, FL USA; [2] South Florida Water Management District, West Palm Beach, FL USA

Introduction

The six Everglades Stormwater Treatment Areas (STAs) are comprised of multiple wetland cells, many of which have extremely long flow paths (up to 7 km). To date, several STAs, most notably STA 3-4 and STA-2, have performed well, providing a long-term mean outflow total phosphorus (TP) concentration of approximately 20 µg/L. By contrast, STA-5 has consistently under-performed (Pietro et al., 2008), but the reason for this wetland's substandard P removal performance is not well understood. We evaluated gradient (inflow to outflow) profiles in water column and soil P levels in both STA-2 and STA-5 flow paths (Figure 1) to determine whether internal P gradients can provide insight into differences in the P removal efficiencies of these wetlands.



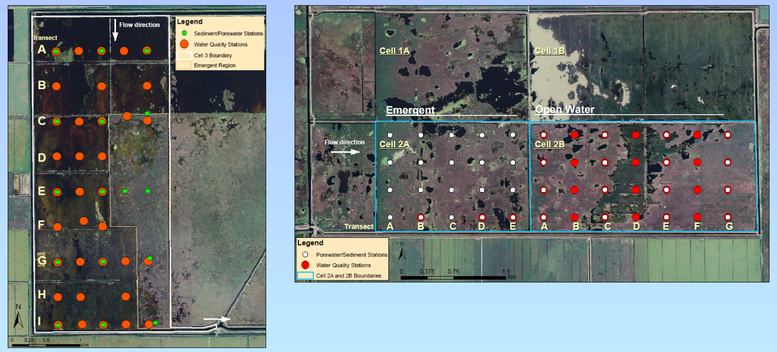


Figure 1. An aerial representation of STA-2 Cell 3 (left panel) showing sample transects "A" through "I", with sample stations depicted along each transect. The STA-5 central flowpath (emergent macrophyte cell 2a and open water/SAV cell 2b) along with sample station locations (right panel).

Methods

We reviewed and summarized historical mass P loadings and removal rates for a flow path in STA-2 (Cell 3), and in STA-5 (Cells 2a and 2b, which comprise the central flow path). Submerged aquatic vegetation (SAV) communities (i.e., *Najas guadalupensis, Potamogeton illinoensis, Chara spp.,* and *Hydrilla verticillata)* cover nearly two-thirds of the 898 ha STA-2 Cell 3 footprint, and the remaining one-third (eastern side) of the cell is populated by emergent macrophytes. In September 2005, we collected soil samples (0-10 cm depth) using a 10 cm diameter coring device at locations along transects oriented perpendicular to the inflow (Figure 1). Soil porewater was obtained by centrifugation and analyzed for soluble reactive P (SRP). Bulk soils were analyzed for TP. One month later, surface water was sampled along transects in the wetland, and analyzed for TP, soluble reactive P (SRP) and total soluble P (TSP). Dissolved organic P (DOP) was calculated as TSP – SRP, and particulate P (PP) was calculated as TP – TSP. The mean hydraulic loading rate (HLR) to the flow path during the two weeks prior to water sampling was 0.04 m/day.

We performed a similar sampling effort in the 831 ha central flow path of STA-5 in late 2007 (Figure 1). The upstream wetland in the flow path (Cell 2a) is dominated by emergent macrophytes (i.e., *Typha domingensis* and *Polygonum spp.*), and flows into the mostly open water Cell 2b, which at the time of sampling supported sparse populations of SAV (i.e., *Ceratophyllum demersum* and *Hydrilla verticillata*). In this flow path, sample sites were established in a similar configuration as in STA-2, with transects situated at various distances perpendicular to the inflow (Figure 1). Soils were sampled in the same manner as in STA-2. Porewater samples were collected at a 6 – 10 cm depth in the soil profile using a "sipper". Due to the shallow water depth in Cell 2a, sampling for water quality was limited to one station along each of the B, D, and E transects. The water quality transects were sampled one month prior to the porewater and soil sampling effort, during a period of no flow.

Results and Discussion

From 2002 through 2007, mean inflow and outflow TP concentrations for STA-2 Cell 3 (96 and 18 µg/L, respectively) were lower than those for the STA-5 central flow path (209 and 128 µg/L, respectively) (Figure 2). During this period, STA-2 Cell 3 removed an average of 82% of the inflow water P load of 1.4 g P/m^2-yr, whereas only 56% of the 2.4 g P/m^2-yr load entering the STA-5 central flowpath was sequestered. In 2007, P loads entering STA-5 Cells 2a and 2b were considerably reduced due to drought conditions and construction activities. Portions of the wetland dried out during this period, which caused a subsequent export of P upon reflooding (Figure 2).

Internal water quality sampling along transects in STA-2 Cell 3 revealed a rapid decline of all P species (SRP, DOP and PP) within the first half of the cell, with little further reduction observed in the back half of the wetland (Figure 3). Other sampling events in this cell (25 total) under a range of inflow conditions have revealed a similar pattern, with low outflow TP concentrations dominated by PP and DOP fractions (DB Environmental, Inc., unpublished data). In contrast to the trends observed in STA-2 Cell 3, the STA-5 central flow path revealed relatively consistent water column TP levels through the emergent macrophyte-dominated Cell 2a, markedly higher TP levels at the inflow of Cell 2b, and then a reduction in [TP] with distance through this open water/SAV wetland (Figure 3). Particulate P was the principal P species present in the water column throughout the central flow path of STA-5. The prevalence of PP may have been due to phytoplankton in the water column, since the wetland was stagnant (no inflow) at the time of sampling, and previous studies have demonstrated that phytoplankton can proliferate in STA cells, even under flowing conditions (Dierberg et al., 2006).

In STA-2 Cell 3, soil TP concentrations ranged from 813 to 514 mg/kg, and exhibited a slight decline from inflow to outflow regions (Figure 3). The upstream cell (2a) of the STA-5 central flow path exhibited a similar range in soil TP, with no discernable inflow to outflow gradient. By contrast, the soil in the downstream cell (2b) displayed increasing TP content with distance from the inflow, with levels of 705 and 1834 mg/kg found at the wetland inflow and outflow, respectively.

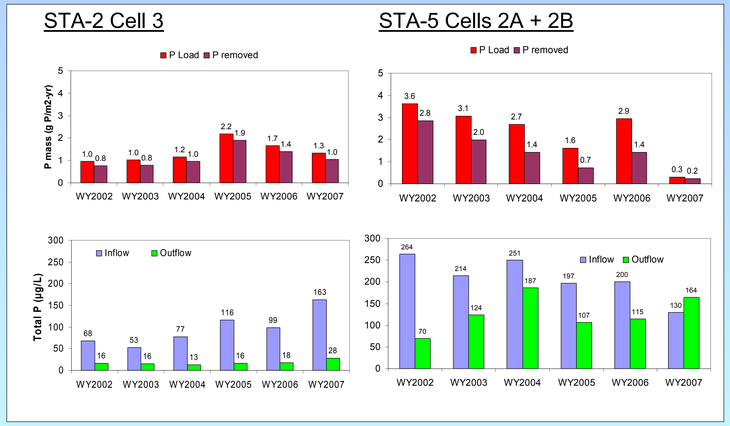


Figure 2. Mass P loading and removal rates (top panels) and mean inflow and outflow TP concentrations (bottom panels) for STA-2 cell 3 (left column) and STA-5 central flow path (Cell 2a inflow and Cell 2b outflow) (right column) for Water Years 2002 through 2007.

Soil porewater SRP concentration trends in STA-2 Cell 3 tended to reflect the water quality P gradient, with highest concentrations near the inflow and lowest levels at the outflow (Figure 3). By contrast, porewater SRP concentrations were relatively low in STA-5 Cell 2a, with little spatial gradient observed. This may be due to the presence of emergent macrophytes, which reportedly have the ability to "mine" labile soil P pools, such as porewater SRP (White et al., 2004). Despite the high soil TP concentrations along the outflow region (E and G transects) in Cell 2b, we observed a dramatic decline in porewater SRP levels from inflow to outflow regions of the wetland (Figure 3).

To a large extent, sediment chemical characteristics of south Florida wetlands reflect the historical P loading conditions (Fisher and Reddy 2001). Because of internal (sediment to water column) P loading, sediment characteristics also can influence P removal performance of the STAs. Such internal loading may be most readily detected under conditions of low external flows and loads, such as we observed during our sampling effort in STA-5 Cells 2a and 2b. The spatial gradient in Cell 2b surface waters, which paralleled trends in porewater SRP, suggest that internal loading may be influencing water column TP under stagnant conditions. Additional monitoring is needed, particularly under flowing conditions, to further examine both sediment and water column P profiles along the STA-5 flow paths.

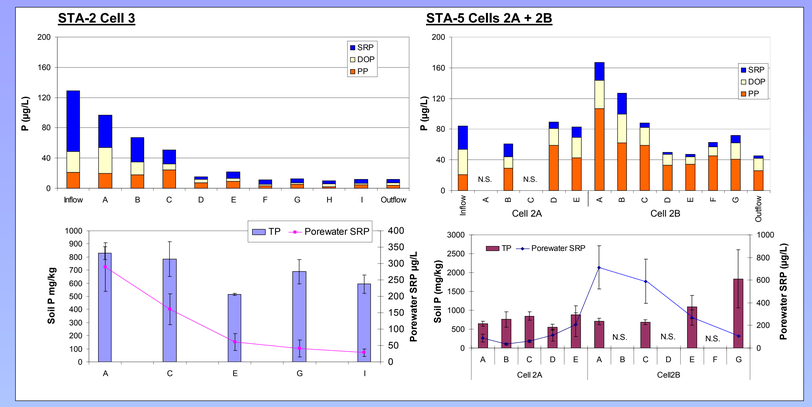


Figure 3. Top panels depict water column P species along sampling transects in STA-2 cell 3 (left column) and STA-5 cells 2a and 2b (right column). See Figure 1 for transect locations. Bottom panels illustrate the relationship between soil TP (mg/kg) on the left y-axis and porewater SRP (µg/L) on the right y-axis. Error bars represent ± 1 standard error of samples that were taken at multiple stations along each transect and then averaged. N.S. = no sample.

Conclusions

STA-2 Cell 3 has consistently provided lower outflow TP concentrations than the STA-5 Cells 2a + 2b flowpath, the latter of which has received both higher inflow TP concentrations and P loads during the past 5 years. Our internal sampling in STA-2 Cell 3 demonstrates a consistently declining inflow to outflow gradient in both soil porewater and surface water P concentrations. A porewater SRP gradient was observed in STA-2 Cell 3 and STA-5 Cell 2b (both of which are SAV wetlands), although concentrations in Cell 3 were markedly lower than those in Cell 2b. By contrast, the upstream STA-5 Cell 2a lacked a well-defined porewater gradient, which may have been due to the depletion of labile soil P pools by emergent vegetation in this cell. Additional internal sampling will better define sediment and water column P profiles along the STA-5 flow paths, and should provide insight into factors influencing P removal performance of these treatment wetlands.

Acknowledgements

Financial support was provided by the South Florida Water Management District and the Everglades Agricultural Area Environmental Protection District. The authors wish to thank Michelle Kharbanda and Kevin Grace for data analyses and Stacey Cote and Nancy Nill for field assistance. Laboratory analyses were performed by Jaimee Henry, Nichole Larson, and Karen Wiggins.

References

Fisher, M.M., K.R. Reddy. 2001. Phosphorus flux from wetland soils affected by long-term nutrient loading. J. Environ. Qual. 30:261-271.

Dierberg, F.E., J. Potts, and K. Kaštovská. 2006. Alterations in the suspended algal abundance, distribution, and diversity within a stormwater treatment area in south Florida, USA. Verh. Internat. Verein. Limnol. 29:2227-2231.

Pietro, K., R. Bearzotti, G. Germain, N. Iricanin. 2008. Chapter 5: STA Performance, Compliance and Optimization. South Florida Environmental Report, South Florida Water Management District, West Palm Beach, FL.

White, J.R., K.R. Reddy, J. Majer-Newman. 2004. Hydrologic and vegetation effects on water column phosphorus in wetland mesocosms. Soil Sci. Soc. Am. J. 70:1242–1251.

Contact Scott Jackson
DB Environmental, Inc. 365 Gus Hipp Blvd. Rockledge, FL 32955
Phone: 561-685-5095; Fax: 561-784-7890
Email: scott@dbenv.com

DB Environmental