Restoration Strategies Science Plan

Detailed Study Plan

The Effect of Vertical Advective Transport (Positive Seepage) on Total Phosphorus Concentrations in the STAs

OVERALL STUDY PLAN SUMMARY

The objective of this study is to quantify the relative magnitude of vertical advective transport (positive seepage) of phosphorus (P) across the soil-water interface. The study will determine if the internal P load from positive seepage into the water column contributes to Everglades Stormwater Treatment Area (STA) discharge concentrations, especially at low water column P concentrations that characterize the end of the STA treatment train. In addition, the study will evaluate management alternatives that may reduce or eliminate the positive seepage.

BASIS FOR THE PROJECT

The STAs (STA-1E, STA-1W, STA-2, STA-3/4, and STA-5/6) were built south of Lake Okeechobee to reduce TP concentration of surface water runoff prior to discharge into the Everglades Protection Area (Figure 1). P loads to the water column of STAs are primarily from surface runoff due to lateral inflows (from pumps and structures). Additional loads include advection (seepage), resuspension and/or diffusion from the STA soils, decomposition of litter and sloughing from vegetation. Past studies have focused on the role of structure flows and P loads on STA performance. These studies demonstrated that P loading from the soil to the water column can be significant, reducing the overall ability of STAs to reach the water quality based effluent limit (WQBEL). Loading from the soil to the water column has been attributed to translocation by aquatic vegetation, plant death and subsequent mineralization of the litter, and diffusion from the soil/pore water to the water column. The effect of vertical advection due to movement of water-either from positive seepage originating from surrounding areas with higher water levels-may contribute to this internal loading through enhanced flux of dissolved P or movement of mineralized or organic particles into the water column. The amount/rate of positive seepage has not been measured. The objectives of this study are to:

1. Quantify the relative magnitude/importance of P loading attributable to positive seepage across the soil/water interface.
2. Examine the methods to reduce the positive seepage by increasing the water column depth or reducing the piezometric force.

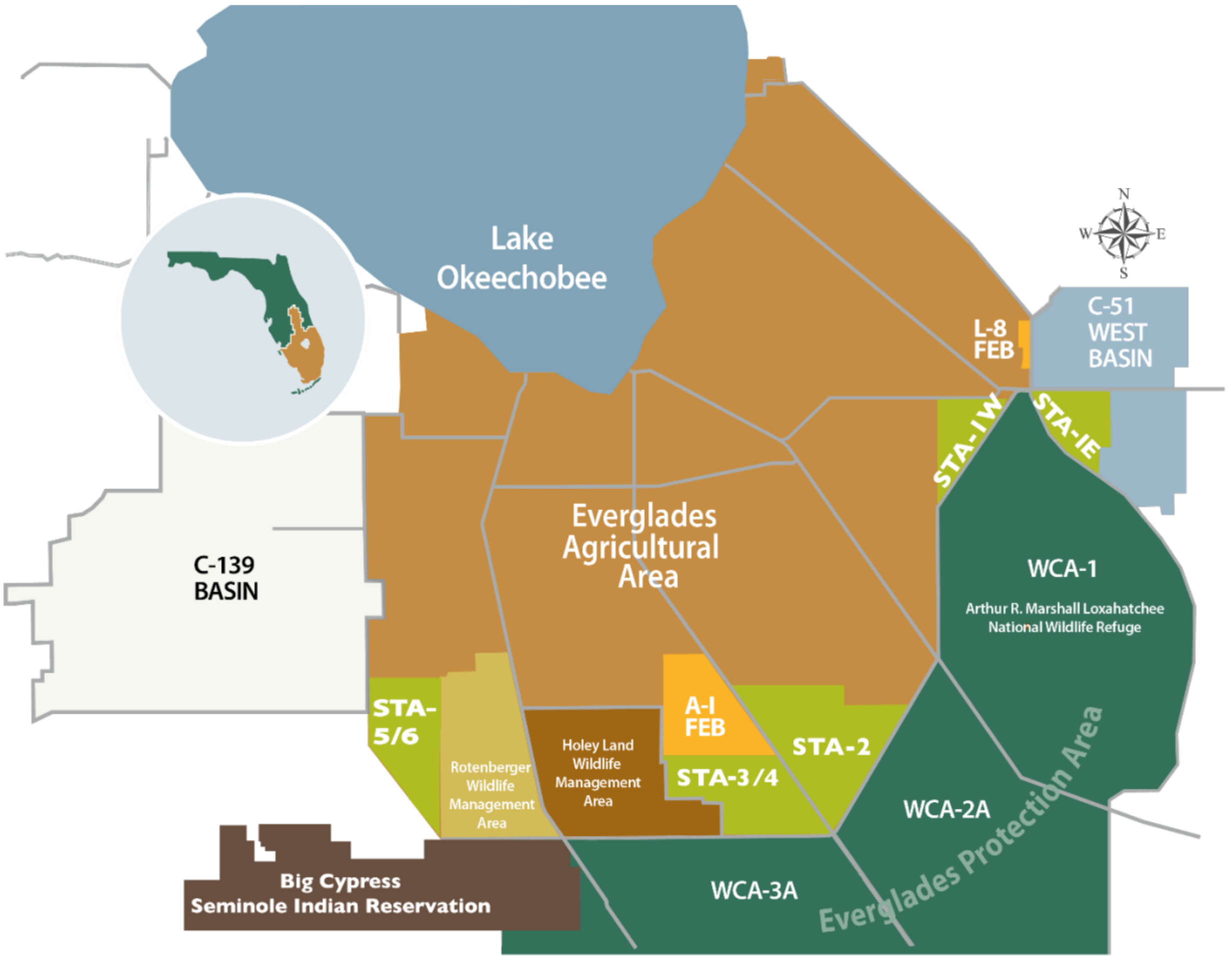

Figure 1. Location of the Everglades Stormwater Treatment Areas (STAs): STA-1 East (1E), STA-1 West (1W), STA-2, STA-3/4, and STA-5/6 in relation to the Everglades Protection Area and the dominant STA vegetation communities [emergent vegetation (EAV) or submerged aquatic vegetation (SAV)].

KEY SCIENCE PLAN QUESTIONS ADDRESSED

1) What operational or design refinements could be implemented at existing STAs and future facilities, including STA expansions and FEBs (Flow Equalization Basins)/reservoirs, to improve and sustain STA treatment performance?
2) How can internal loading of P to the water column be reduced or controlled, especially in the lower reaches of the STAs?

3) How can the biogeochemical or physical mechanisms, including internal flux of P, be managed to further reduce soluble reactive P, particulate P, and dissolved organic P concentrations at the outflow of the STAs?

SCIENCE PLAN SUBQUESTIONS ADDRESSED

- Will reduced advective loading from the soil to the water column reduce P concentrations out of the STAs?
- Are there things we can do in the STAs to enhance settling, filtering, transpirational flux, to reduced particulate P through water column?

PROJECT TIMELINE

Study Phase	Activities	Milestones
Phase I	Task 1: Literature review	December 2021
	Task 2: Historical analysis of TP and water levels in outflow cells of the STA	March 2022
	Task 3: Simple numerical model. to evaluate the influence of advection on P concentrations in STA discharge (Stop/Go)	June 2022
Phase II	Task 4: Pilot study (Stop/Go)	November 2022
Phase III	Task 5. Field measurements experiments (Stop/Go)	August 2023
Phase IV	Task 6: Cell management recommendations	September 2023

DETAILED STUDY PLAN TASKS

Task 1. Literature Review

Hypothesis:

1) Positive seepage is a significant contributor to the water budgets of constructed wetlands

2) Positive seepage can contribute a significant amount of P to the water column of constructed wetlands
3) Positive seepage can be reduced in constructed wetlands through seepage control and/or management of water levels

Objectives:

Relevant published information will be collected and reviewed, including peer-reviewed journal articles and technical reports. The literature search will be guided by the following topics and research questions:

- What is the contribution of positive seepage (vertical advection) to the water budget of STAs and wetlands?
- What is the contribution of positive seepage (vertical advection) to the P budget of STAs and wetlands?
- What is the range of seepage rates into the STAs?

Task 2. Water Budget and historical analysis of TP and water levels

Hypothesis:

Increased water depth can reduce TP concentrations in the water column by reduction of advective loading from soils into the STA.

Objectives:

Water budgets for selected cells will be developed using observed data from DBHYDRO (SFWMD 2020), previous water budgets (Zhao and Piccone 2020), and seepage estimates (Harvey et al. 2002, Harvey et al. 2004).

TP concentrations and water levels in outflow cells of STAs will be separated into three categories by water depth:

1) shallow – below operational guidelines for stage/water level (1.2 feet),
2) standard – at operational levels (typically 1.2 feet), and

3) deep - above operational guidelines (above 1.2 feet).

Seepage and water budget residuals (based on the water budget), and TP concentration will be compared among the three categories for given cells. If advective loading (e.g. seepage) affects STA performance for a given cell, then TP seepage and residuals should be related. A report documenting the methods data and findings will be written.

Task 3. Simple numerical model

Hypothesis:

Advective loading can significantly increase water column P concentration within STAs.

Objectives:

A simple numerical model that simulates the hydrology of an STA outflow cell will be constructed. P will be simulated based on a simple model such as LPWEM (Justin et al. 2019). A set of historical inflows with inflow P concentrations of 0.01, 0.015, and 0.020 mg P/L will be established., A positive seepage and associated P concentration (upward advective flow and P load) will be added and a sensitivity analysis conducted for each of the three inflow concentrations to determine the effect flows and P concentrations from this advective load has on the estimated discharge P concentration. The range of internal seepage will be determined from the literature review and best professional judgement. Nomographs will be constructed that plot water TP concentrations against soil TP and seepage rate. The region where the outflow concentrations are at or above 20% of the TP concentrations for 0 seepage will be determined.

A report will be written describing the model and the results.

Stop/Go

District staff will evaluate the results from Tasks 1, 2 and 3 to determine if the study should continue to Phase II. This will be based on an evaluation of the effect that advective loading has on outflow TP concentration. If the loadings are significant enough that they affect the performance of STA flow-ways, then Phase II may proceed.

Phase II. Pilot Field Experiments

Task 4. Pilot Seepage and Piezometer measurements experiments

Hypothesis:

1) Advective loading can be affected by changing water levels in STAs

2) Reducing advective loading will reduce water column P concentration within STAs.

Objectives:

A pilot seepage study will be performed in one STA cell (either STA 2 Cell 1, STA 2 Cell 3, or STA 3/4 Cell 2B). Three seepage meters and three adjacent piezometers will be installed. Three lysimeters will also be installed to capture the dissolved P concentrations in the upper 10 to 20 cm of soil at each location. All of these meters and piezometers will be located in representative areas of the STA cells. Measurements will be recorded over a period of a few weeks to one month depending on the rate of seepage measured. The seepage volumes, piezometric heads, and water depth measurements will be collected on a daily to weekly basis. In addition, three sets of water samples (3-lysimeter; 3-adjacent wetland water column, 3-pieziometers) will be collected for laboratory water quality analyses (P species; N species; ions; Ca; Fe).

A report will be written describing the methods and the results.

Stop/Go

If the results of the pilot study indicate that

1) Seepage rates are measurable
2) Piezometer measurements are consistent with the seepage rates
3) Water quality measurements from lysimeters are above detection for dissolved TP and can be used to indicate a potential internal P load from seepage
4) Variation within each measurement type is acceptable to obtain a reasonable signal
5) Measurements are large enough to affect the wetland water quality,

Then proceed to Phase III

Phase III. Field Seepage Measurements

Task 5. Seepage Measurements

Two well-performing flow-ways and two poorly-performing flow-ways will be selected based on historical analyses and past overall performance (Figure 2). Potential cells include STA-2 Cell 3, STA 3/4 Cell 2B (well performing), STA 1-E Cell 4S and STA 5/6 Cell 5-1B (poor performing). Sets of three seepage meters will be set up in the outflow region of each of these cells. These meters will be placed in representative areas. Three piezometers and three lysimeters will be located adjacent to the seepage meters. Measurements will be recorded during one wet season and one dry season.

In each cell location, a minimum five sets of water samples (3- lysimeter, 3- wetland) and five sets of seepage and piezometer measurements will be collected over one wet and one dry season. Sampling in these four cells is not required concurrently. however, measurements should be made over the same wet season and dry season.

A report will be written describing the methods and the results.

Stop/Go

District staff will evaluate the results from Task 5 to determine if the effects of advection/seepage are measurable and large enough to affect meeting the WQBEL. If so, the study may continue to Phase IV

Figure 2. Location of cells selected for potential seepage measurements (see Figure 1 for regional locations).

Phase IV

Task 6. Cell Management Recommendations

Hypothesis:

1) Advective loads can be managed
2) Controlling advective loads will reduce P concentration in STA outflows

Objectives:

Phase I, II and III reports will be used to develop management options to reduce advective loading to STA outflows. Based on hydrology, location, and outflow P concentration, outflow cells will be identified as candidates and ranked for the need to reduce advective loadings. These management options may include, but are not limited to, increased water depths in the cells, cutoff walls to reduce groundwater infiltration and thus upward advection, and seepage canals with enhanced drainage (pumps).

Internal Staffing:

List Functions	Skill of Functional Employees	Identify Employees	Total FTEs Required for Complete Project
Project Lead	Principal Scientist	Tom James	0.2
Project Support	Hydrogeologist	Justin Zumbro	0.1
Project Support	Hydrogeologist	Steve Krupa	0.1
Project Support	Senior Environmental Scientist	Hongjun Chen	0.1
Project Support	Scientist 4	TBD	0.1
Total Resource Requirements			0.6

Estimated costs

Study Phase	Activities	Completion Date
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Phase II	Task 4: Pilot study (Stop/Go)	September 2022
Phase III	Task 5. Field measurements experiments (Stop/Go)	September 2023
Phase IV	Task 6: Cell management recommendations	December 2023
Total		

REFERENCES

Harvey, J. W., S. L. Krupa, C. Gefvert, R. H. Mooney, J. Choi, S. A. King, and J. B. Giddings. 2002. Interactions between Surface Water and Ground Water and Effects on Mercury Transport in the North-central Everglades. Water-Resources Investigations Report 02-4050. Page 91. United States Geological Suvery, Reston Va. .

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SFWMD. 2020. DBHYDRO Browser User's Guide (September 2020 revised). South Florida Water Management District, West Palm Beach, Florida.

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