Appendix 5C-1: Use of Soil Amendments/ Management to Control Phosphorus Flux

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INTRODUCTION

The objective of this study is to investigate whether internal loading of phosphorus (P) in the stormwater treatment areas (STAs) (i.e., the flux of P from the soil to the overlying water column) can be reduced by the application of soil amendments and/or soil management techniques and thereby lower outflow total phosphorus (TP) concentrations. The original plan for the study was to conduct it in three phases. Phase I included preliminary data evaluation and assessment tasks. Subsequent efforts would involve bench-scale experiments (Phase II) followed by large-scale field trials conducted in the STAs (Phase III) to document the treatment efficacy of select soil amendments and/or soil management techniques. All work associated with Phase I has been completed; findings from Phase I and a decision regarding post-Phase I work are reported in Chimney (2015) and summarized below.

METHODS

Phase I of this study included three tasks:

- Task 1 – Expand an existing literature review on technologies for controlling soil-P flux in wetlands or lakes
- Task 2 – Summarize findings of past South Florida Water Management District (SFWMD or District) supported projects relevant to this study
- Task 3 – To the extent practicable, assess the feasibility of implementing any of these technologies at full-scale in the STAs

The Phase I literature review started with the initial set of papers and project reports compiled during development of the District's Restoration Strategies for Clean Water for the Everglades (Restoration Strategies) *Science Plan for the Everglades Stormwater Treatment Areas* (Science Plan; SFWMD 2013). This review was augmented with additional references found relevant to soil amendments. The focus of this effort was to generate a list of materials that have been proven to be capable of sequestering P and soil management techniques that may reduce soil P flux and that could potentially be used in the STAs. This review was not an exhaustive compilation of all research conducted on these materials/techniques nor was it an attempt to elucidate in detail the biogeochemical mechanisms involved in P sequestration.

The feasibility of using soil amendments or soil management techniques to reduce outflow TP concentrations in the STAs was evaluated from the viewpoint of constructability, treatment efficacy, operations/regulatory issues, and economics. Not all these areas could be fully addressed in Phase I of this study. Costs were estimated for (1) the construction and infrastructure associated with large-scale test

facilities that would be needed to conduct field trials in the STAs, and (2) implementing soil amendments and soil management techniques at full-scale in the STAs under a single scenario, i.e., installation throughout the ~12,660 hectares (ha) in the STAs that are maintained as submerged aquatic vegetation (SAV) cells. The original conceptual design for the large-scale test facilities was later revised to include an option that utilized two cells in STA-1 West (STA-1 W; Expansion Area #1) to test the efficacy of soil inversion and a second option that called for subdividing select treatment cells within STA-1 East, STA-1W, STA-3/4, and STA-5/6 to test several different technologies.

RESULTS AND DISCUSSION

A "soil amendment" was defined for this study as any material that sorbs soluble P and includes (1) liquids, slurries or fine-grained particulate materials that can be incorporated into or broadcast on top of the soil (e.g., lime, drinking water treatment residuals, and Phoslock®), and (2) coarse-grained particulate materials that typically are used as the substrate in horizontal subsurface/vertical flow wetlands or in-ground/in-stream filter systems (e.g., crushed mollusk shells and various slags). Materials used as soil amendments are typically rich in metal cations, primarily aluminum, calcium, iron, or magnesium, that readily bond with dissolved P.

Over 100 different materials that sorb P and have been tested for use as a soil amendment were identified during the literature review comprising approximately equal numbers of natural, man-made, and waste by-product materials. Because of marked differences in experimental methodology and study conditions that influence P sorption (e.g., water temperature and pH, amendment particle size and porosity, amendment mass to solution volume ratio, contact time of amendment with water, time required to saturate the amendment with P, initial P concentration, and concentration of dissolved organic material and other anions that compete for P binding sites), it was not possible to normalize results from these studies and directly compare their P sorption capacities. Furthermore, the majority of soil amendments have been studied only in short-term laboratory experiments. It is difficult to predict how these materials would perform long-term under field conditions as P retention in the laboratory can be much higher compared to rates obtained in-situ. The few long-term field data that are available suggest that soil amendments become saturated and lose their effectiveness within a few years after application and that five years may be the maximum treatment period that reasonably can be expected. Furthermore, many of these materials may not meet one or more of the other criteria desirable in a soil amendment, most notably, in terms of low cost, local availability in sufficient quantities needed for use in the STAs, or no impact to downstream flora and fauna.

Three soil management techniques were discussed during the development of the Science Plan as possible strategies for reducing soil-P flux in the STAs; soil capping, soil inversion, and soil removal. Soil capping (with alum) and sediment removal have been used in a number of lake restorations. However, there is no documentation that any of these techniques have been used successfully in treatment wetlands.

The District has carried out a number of projects that are relevant to this study. A short-term laboratory experiment found that broadcasting a soil amendment (Reclime®) on top of sediment cores was much more effective at reducing soil-P flux to the overlying water column immediately after the cores were flooded versus the inhibition of soil-P flux achieved with mixing the amendment into the soil. The District has evaluated the effectiveness of soil capping; a 2-ha wetland cell capped with limerock achieved an outflow flow-weighted mean (FMW) TP concentration of 18 micrograms per liter (µg/L) during a 9-month period of optimal performance. The potential benefit of soil removal to reduce internal P loading was tested in the field with two different platforms. In the first study, another 2-ha cell was scraped down to the limestone caprock and achieved an outflow FWM TP concentration of 16 µg/L during the same 9-month operational period. In the second study, the 40-ha periphyton-based STA cell in STA-3/4 also was scraped down to the limestone caprock and had annual outflow FWM TP concentrations that ranged from 8 to 13 µg/L for nine consecutive operational years. A number of pilot projects have demonstrated the utility of inverting the

topsoil with the subsurface soil horizon to reduce copper concentrations at the soil surface or to reduce the flux of soil-P to the water column.

The District has experience with the types of large-scale engineering and construction practices that would be required to employ soil amendments or soil management techniques at full-scale in the STAs. Therefore, there is no reason from a constructability perspective that these techniques would not be practicable. Despite the number of studies focused on soil amendments and soil management, no published data were found that demonstrated the long-term efficacy of using these approaches in treatment wetlands. There are potential regulatory issues related to using soil amendments or soil management techniques in the STAs. However, they were not deemed serious enough to prohibit the District from using any of these technologies. The estimated costs to apply a soil amendment, install a limerock cap, or invert the surface layer of soil over the entire STA surface area dominated by SAV were $99 million, $876 million and $86 million, respectively. All costs should be regarded as order of magnitude estimates and a wide range of values could be generated by varying one or more of the scenario assumptions. The cost threshold at which any soil amendment or soil management technique becomes economically infeasible for the District to implement in the STAs is outside the scope of this study.

Considering the uncertainties in treatment efficacy of these technologies, potential impacts to STA operations, and the economics associated with conducting large-scale field trials and implementing any of these technologies at full-scale in the STAs, this study moved forward only with planning and budgeting associated with the option to test soil inversion at large scale in the STA-1WX1 (Expansion Area #1) and Phases II and III will not be implemented for other technologies at this time. STA-1WX1 (Expansion Area #1) is scheduled to be flow-capable on December 31, 2018. Accordingly, this study will be on hiatus until early 2018.

LITERATURE CITED

Chimney, M.J. 2015. *Phase I Summary Report for the Use of Soil Amendments/Management to Control P Flux Study*. Technical Publication WR-2015-006, South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2013. *Science Plan for the Everglades Stormwater Treatment Areas*. South Florida Water Management District, West Palm Beach, FL.