Chapter 4: Stormwater Treatment Technologies

Jana Majer Newman, Gary Goforth, Michael J. Chimney,
Jennifer Jorge, Tim Bechtel, Guy Germain,
Martha K. Nungesser, Chandra Pathak, Darren Rumbold,
Jose Lopez, Larry Fink, Binhe Gu, Kimberleigh Cayse,
Ron Bearzotti, Drew Campbell, Christy Combs,
Kathy Pietro, Nenad Iricanin, Richard Meeker,
Geoff West and Neil Larson

CHAPTER ORGANIZATION

As part of the restructuring of the Everglades Consolidated Report (ECR), Chapter 4 now includes all information pertinent to Stormwater Treatment Areas (STAs) that in prior ECRs was found in Chapters 4, 6, 7 and 8 (2000 ECR, 2001 ECR). This new Chapter 4 has been retitled "Stormwater Treatment Technologies" and is organized into three sections:

- STA Performance and Compliance (Chapter 4A)
- STA Optimization (Chapter 4B)
- Advanced Treatment Technologies (Chapter 4C).

This chapter is written strictly as an update to Chapter 4 of last year's ECR. As in the other chapters of this report, Chapter 4 emphasizes information for the period May 1, 2001 through April 30, 2002.

SUMMARY AND FINDINGS

STA PERFORMANCE AND COMPLIANCE

An overview of STA operations, vegetation, phosphorus (P) and water quality compliance is presented in this section for each of the STAs, which form the Everglades Construction Project (ECP). Water quality parameters addressed include nutrients, dissolved oxygen (DO), pesticides and mercury. This information is provided to document compliance with appropriate conditions of the Everglades Forever Act (EFA; Section 373.4592, Florida Statutes) and USEPA National Pollution Discharge Elimination System (NPDES) permits. Appendices provide additional details of the monitoring program as required by operating permits.

- Four of the six STAs (STA-1 West, STA-2, STA-5 and STA-6, Section 1) were operational and removed P that otherwise would have gone into the Everglades Protection Area (EPA). During Water Year 2002 (WY02), the STAs treated 826 hm^3 (670,585 ac-ft) of water and removed 83 metric tons of P. This was a marked increase from WY01, when, due to drought conditions, the STAs treated only 219 hm^3 (177,100 acre feet) of water and removed 24 metric tons of P.
- The composition of the plant communities in the STAs varies among the treatment cells but is generally dominated either by cattail (*Typha* spp.) or submerged aquatic vegetation (SAV) and periphyton.
- Water quality monitoring within and downstream of the STAs demonstrated that the four STAs in operation are in full compliance with state operating permits.
- In early WY02, operation of STA-1 West was influenced by the latter stages of a severe drought in South Florida, but a typical rainfall cycle returned in June 2001, and normal wet-season operation of most water control structures resumed. No supplemental water deliveries were required. Dry-season operation of STA-1 West began in December 2001 and continued through the end of this reporting period.
- While STA-2 cells 2 and 3 achieved their start-up criteria in September and November 2000, respectively, cell 1 still had not done so at the end of this reporting year. In August 2002 the South Florida Water Management District (SFWMD or District) was issued a permit modification to allow cell 1 to operate in a flow-through mode. This is expected to reduce methylmercury (MeHg) production and bioaccumulation rates by altering cell hydrology and surficial sediment chemistry. Expanded monitoring is being conducted to better understand the causes of excessive MeHg production and identify short- and long-term measures to address this concern.
- Operation of STA-5 over the past year was substantially influenced by the latter stages of the most severe drought ever recorded in South Florida. Three of the four treatment cells dried out this past year. When normal wet-season rainfall returned in June 2001, stormwater runoff from the C-139 basin resumed flow through STA-5. Dry-season operation of STA-5 began in December 2001 and lasted through the end of this reporting period.
- STA-6 section 1 experienced two separate dryout events, in April and May 2002. No supplemental water delivery was required because the plant community in the STA is moderately drought resistant. Wet-season operations followed normal patterns for this STA.

STA OPTIMIZATION

Research into optimization of the STAs continued over the past year. Previous ECRs have presented analyses and information on the state of knowledge about the Everglades Nutrient Removal Project and the STAs. This year's ECR updates ongoing research and summarizes major new findings since the 2002 ECR was published.

The EFA requires the District to conduct research and monitoring programs to optimize the nutrient removal performance of the STAs. Information is derived from practical experience operating the STAs, analysis of STA performance data, experiments being conducted in the STA-1W test cells, small-scale mesocosm experiments, analysis of data from other wetlands, and eventually through simulation of operational scenarios using a dynamic water quality model.

- Residual error in the water and total phosphorus (TP) budgets for STA-1W cell 5 was unacceptably high. To address this problem the District is resurveying the head and tailwater elevations at all new STA-1W water control structures. These revised data will be used to verify stage calculations and flow equations associated with these structures and correct flow estimates, as necessary. In addition, the District is installing autosamplers to collect time- or flow-proportioned water quality samples that will improve estimates of TP concentrations at these structures.
- The pulsed hydraulic loading rate (HLR) and low- and high-depth experiments conducted in STA-1W were concluded in WY01–02. These experiments investigated the impact of altering these parameters on STA treatment performance.
- The mean hydraulic retention time (HRT) based on the tracer data for test cell NTC-05 was about the same as its nominal HRT, indicating that this system had no major dead zones or short circuits. Low-depth test cells had tracer HRTs less than their nominal HRTs, indicative of possible dead zones. The two south control test cells had tracer HRTs greater than their nominal HRTs, suggesting that water movement bypassed part of the system (i.e., short circuiting) or that the average bottom elevation was inaccurate, leading to an incorrect volume estimate.
- The high- and low-depth experiments conducted at the north test cells all resulted in a slight increase in TP removal. The large changes in HRT that resulted from altering depth did not have the same effect as was observed during the HLR experiments, where a marked increase in mean TP outflow concentration occurred when HRT was reduced to less than 11 days, but not when HRT was increased. A major difference between these two sets of experiments was the areal TP load. The areal TP load varied considerably during the HLR experiments but not during the depth experiments. Additionally, the mean inflow TP concentration for the depth experiments (45 μg/L) was less than half the mean concentration during the HLR experiments (100 μg/L). In cattail-dominated wetlands that receive relatively high inflow TP concentrations, such as at the front-end of an STA, depth is apparently not an important operational constraint; rather, TP loading has much greater influence on treatment performance.
- Total P loading to STA-5 was almost three times higher in WY01–WY02 compared to WY00–WY01 (18,338 versus 54,140 kg). Also, the south flow-way received more TP mass than the north flow-way in both years (90 and 10 percent, respectively). The difference between flow-ways was attributed to the Deer Fence Canal, which discharged directly into the south flow-way. Despite the variation between years in TP loading, STA-5 removed proportionately more TP mass in WY01–02 than in WY00–01 (68 versus 58 percent of inflow) and had a substantially lower mean outflow TP concentration (73 versus 154 μg/L, respectively). The increase in treatment performance in WY01–02, despite the greater TP loading, was attributed to development of the wetland plant community.

ADVANCED TREATMENT TECHNOLOGIES

The District is nearing the conclusion of an ambitious research program for testing the ability of several Advanced Treatment Technologies (ATTs) to remove TP from waters entering Florida's Everglades. The goal of this research program is to identify technologies that will meet the long-term water quality objectives for the Everglades in accordance with the EFA. The criteria being used to evaluate these treatment technologies are specified by the EFA: TP load reduction; TP discharge concentration reduction; distribution and timing of water delivery to the

EPA; compliance with water quality standards; compatibility of treated water with natural populations of aquatic flora or fauna in the EPA; cost-effectiveness; and schedule for implementation. Other evaluation criteria include technical/scale-up feasibility, possible adverse environmental impacts and local acceptability. The current studies have provided information on TP removal performance, estimated costs and the ability of the technology to meet the EFA's requirement so that,

"…discharges into the Everglades Agricultural Area canals and the EPA prevent an imbalance in the natural populations of aquatic flora or fauna in the EPA and provide a net improvement in the areas already impacted."

Based on ATT research completed to date, it is clear there are two classes of treatment technologies that may be used to meet the long-term water quality requirements of the Everglades:

1. **Biological treatment technologies**. Includes SAV and periphyton-based Stormwater Treatment areas (PSTA).
2. **Chemical treatment technologies.** Includes microfiltration, chemical treatment/solids separation (CTSS) and other chemical treatment-derived vendor technologies.

It is expected that the District will continue research on promising ATTs at least until the Everglades TP criterion and method of compliance are established by the Florida Department of Environmental Protection and the Environmental Regulation Commission (ERC). Current findings for each ATT project are summarized below.

Submerged Aquatic Vegetation/Limerock (SAV/LR)

The SAV study over the last year has focused on field-scale SAV-dominated systems, such as the test cells, and STA-1W cells 4 and 5 in the development of a process model for comparative analysis and a scale-up exercise, as well as comparative studies of long-term retention rates found in natural SAV systems.

Test cell and STA-1W cell 4 sediment analysis indicates that P storage and accrual rates are dependent on nutrients and HLR. Generally, the cells that received higher TP loading had higher sediment TP concentrations and accrual rates.

In hard-water systems, such as STA-1W cell 4, the P sequestered within the SAV community was associated with a fairly stable, calcium-bound sediment fraction.

Based on the SAV model used in the Standard of Comparison exercise and the demonstrated long-term performance of STA-1W cell 4, an SAV wetland can be expected to reduce post-STA TP concentrations to about 20 μg/L. Additionally, the model was used to extrapolate a two-year period of optimal performance of STA-1W cell 4, along with improved system hydraulics, and forecast an outflow TP concentration of 14 μg/L within a reduced footprint.

Periphyton-based Stormwater Treatment Area (PSTA)

Phase 2 of the Periphyton-based Stormwater Treatment Area (PSTA) research study, which included model development and scale-up cost estimates, has been completed, and phase 3 monitoring of an 8.1 ha (20 acre) field-scale demonstration project was begun.

Test cell research has shown that with a mean inflow TP concentration of 23 μg/L, a mean outflow TP concentration of 12 μg/L was sustained for more than a year in a shellrock-based PSTA system.

Based on the PSTA process model used in the Standard of Comparison exercise and the demonstrated performance of the south test cells, the area required by a PSTA system was most sensitive to sediment nutrient concentration and wetland hydraulic efficiency.

The cost estimates of the PSTA system derived from the scale-up exercise were most sensitive to the depth of limerock added and the cost of additional land area.

Preliminary monitoring data from the field-scale system indicated that groundwater seepage might be a significant factor in the TP removal performance of a full-scale system.

Chemical Treatment/Solids Separation (CTSS)

The District operated a pilot-scale CTSS facility within the C-11 basin between August 27 and November 1, 2001. Additionally, the District operated a larger CTSS facility located at the STA-1W north test cells in combination with an SAV-dominated wetland.

The CTSS unit located at the C-11 basin produced TP outflow concentrations less than or equal to 10 μg/L in seven of eight trial runs.

As a result of the CTSS chemical process, the aluminum and chloride concentrations in the outflow of the treated C-11 runoff were greater than the respective inflow concentrations.

On average, the CTSS treatment process removed 99 percent of the fecal coliform bacteria and reduced alkalinity, color, iron, reactive silica, nitrogen, organic carbon and turbidity relative to inflow concentrations.

The CTSS unit located at the STA-1W north site test cells reduced mean inflow TP concentrations from 73 μg/L to 9 μg/L, while the mean outflow from the SAV wetland was 15 μg/L.

Mean total aluminum and chloride concentrations from the CTSS unit were higher than inflow concentrations. This was attributed to the addition of 20 mg/L of aluminum chloride as the coagulant.

Standard of Comparison

The Supplemental Technology Standard of Comparison (STSOC) was designed to ensure that the ATTs could be compared against one another. The CTSS project was the first to complete its STSOC; the results are presented in the 2002 ECR. The results of the PSTA and SAV STSOCs are presented in this year's ECR.

Primary Evaluation Concepts

The STSOC identified and addressed the following nine evaluation concepts:

- The level of TP concentration reduction achievable by the technology (as determined from experimental data)

- The level of TP load reduction (as derived from model data)
- Compatibility of the treated water with the natural population of aquatic flora and fauna in the Everglades
- Cost effectiveness of the technology
- Implementation schedule

Ancillary Evaluation Concepts

- Feasibility and functionality of the full-scale design and cost estimates
- Operational flexibility
- Sensitivity of the technology to fire, flood, drought and hurricane
- Level of effort required to manage, and the potential benefits to be derived from, side streams generated by the treatment process

FUTURE RESEARCH

The District will continue investigating all promising technologies in an effort to reduce outflow TP concentrations from the STAs down to the planning goal of 10 μg/L. Monitoring of the PSTA and SAV test cells located at STA-1W will also continue, along with monitoring of the PSTA field-scale site located west of STA-2. In addition, the District has entered into a cooperative agreement with the University of Florida to investigate several methods of mineralizing the dissolved organic P in STA effluent in an effort to further reduce outflow TP concentrations.

The District will continue analysis of long-term trends in the STAs to provide a basis for improving the treatment performance of these systems. To achieve this goal it is necessary to understand why each of the STAs performs differently and how the various biological and physical components, such as the plant community and sediment, influence TP removal. The District will also continue monitoring the operation and performance of several full-scale SAV treatment systems.

FUNDING

It must be stated that to date no dedicated funding has been identified for implementation of any STA optimization measures, nor for the implementation of ATTs that may be necessary by 2006 to meet the long-term water quality standards for waters discharging into the EPA.