THE DEMONSTRATION PROJECT AND STORMWATER MANAGEMENT

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ABSTRACT

A monitoring project was designed to measure pollutant concentrations as well as the amount of water discharged from an effluent filtration (underdrain) system during storm events. The system was analyzed for water quality discharged from a stormwater pond that ultimately flows into the Tampa Bay estuary in Florida. The volume of stormwater runoff was also measured to estimate a water budget for the system. Also, the water quality and flow discharged through the underground filter system on a daily basis was quantified. The data in this report include nineteen rain events and concluded the first year of the study, which was designed to collect background data before making recommendations and improvements to the systems for phase II of the project.

INTRODUCTION

An important natural process known as rainfall saturates soils, replenishes aquifers and provides water for biological processes. While there are numerous benefits provided by rainfall, there is one important problem associated with rainfall that begins when the first drop contacts the ground, this is known as stormwater runoff. As rainwater mixes with pollutants that have collected on streets, parking lots, sidewalks, rooftops and other impervious surfaces, nonpoint source pollution is introduced into the watershed.

To deal with nonpoint source pollution, the Southwest Florida Water Management District (SWFWMD) issued permits for two stormwater ponds as part of the Florida Aquarium construction in downtown Tampa. The ponds provided an opportunity to study various aspects of stormwater management. Specifically to investigate some of the problems associated with pond maintenance, to educate the public about runoff pollution and to develop strategies to make stormwater systems an attractive landscape amenity. Two monitoring studies were actually conducted, however, for purposes of this paper only one study will be presented. This study evaluated an entire stormwater system using an effluent filtration system with the goal of constructing water and nutrient budgets and is designated “The Whole Pond Study.” The pond on which this paper concentrates has been given the label the Street Pond, for the area of the watershed that it drains.
STUDY SITE

The site is located at the Florida Aquarium at 701 Channelside Drive, Tampa, Hillsborough County, FL (Section 19, Township 29, Range 19). The stormwater ponds are situated between the parking lot and the aquarium building. They discharge to Ybor Channel which leads directly to Tampa Bay, an estuary of national significance, included in the National Estuary program and identified as a water body in need of attention. The wet ponds in this study were quite different from one another and were named to designate the principal type of runoff each pond received (Figure 1). For purposes of this paper only the Street Pond (Pond 3 and Pond 4) will be discussed.

The Street Pond collects runoff from a well-traveled downtown thoroughfare and a large parking garage. The pond is designed to treat 10.4 acres of street and urban runoff. It is an effluent filtration system that uses artificial side drains packed in aggregate to treat stormwater. Filter systems direct low flows through this media to underdrain pipes which, in this case, discharges to the drop box at the outflow. High flows are discharged over the outfall weir.

Figure 1. Site map showing the Street Pond (Pond 3 & 4) and the Building Pond (not included in this paper). Note the runoff to the inflow pipe (6) of Pond 3 (sedimentation basin). Notice the direction of flow towards the outfall (4) in Pond 4 (treatment basin) via (5) and (3), the equalizer pipe.
The Street Pond is actually two ponds connected in the middle with an equalizer pipe. The first pond was designed to act as a sedimentation basin and the second pond was the filtration system with side bank filters located on its south side. Maintenance of filter systems is an important component in keeping effluent filtration systems functional, but unfortunately this is rarely done. This pond was no exception and the drawdown pipes were clogged with debris and the screening material was in disrepair. The Whole Pond Study was conducted to evaluate the water quality and quantity for the inflow, outflow and underdrain system.

MATERIALS AND METHODS

The Street Pond was sampled at the inflow, outflow and underdrain structures, as well as for rainfall, to quantify the flow and water quality entering and exiting the system. The side bank filtration system and the outflow structure were taken into consideration when computing water and flow. Storm water was monitored from November 2000 through August 2001 by collecting flow-weighted composite samples and/or grab samples from the appropriate sampling stations after a rain event. Flow-weighted composite samples were collected at regular intervals in the underdrain pipe to compare with the pond water.

The chemistry laboratory of the Southwest Florida Water Management District (SWFWMD) analyzed water quality samples. Laboratory analyses were performed according to either Standard Methods (A.P.H.A. 1989) or Methods for Chemical Analysis of Water and Wastes (U.S. EPA 1983). Water quality samples were collected to analyze total nitrogen, organic nitrogen, total phosphorus, ortho-phosphorus, copper and lead. Acid was then added to the samples for preservation of metals and nutrients. The samples were placed on ice in coolers and transported to the SWFWMD laboratory for analysis using standard methods.

When analyzing the water quality data, there were a large number of measurements below the laboratory detection limit. When a value was listed below the limit of detection (LOD) then one-half the detection limit was substituted for calculating summary statistics.

To measure inflow hydrology a CR10™ data logger was connected to a Sontek™ velocity meter suspended into the inflow pipe about ten feet before the pipe discharged into the pond. The Sontek™ recorded velocity, which was later converted to flow using the area of the pipe, 1.2 m² (12.5 ft²). An ISCO™ automatic portable sampler packed with ice was used to take flow weighted composite samples in the pipe.

Outflow Hydrology was measured using a CR500™ data logger connected to a float and pulley. The data logger recorded water level from the outflow, this data was used to estimate the amount of flow exiting the pond. The flow data for the weir structure at the outflow were estimated using the standard formula for a rectangular weir with end contractions. Each side of the outfall box was then treated as a separate rectangular weir. Here also an ISCO™ sampler was used to take flow weighted composite samples of the outflow. The underdrain hydrology was measured at the Street Pond using an ISCO™ bubbler flow meter and a Thel-Mar™ volumetric weir installed in the pipe.
RESULTS

Data from the Street Pond were collected and analyzed for water quality and flow for the period November 2000 to August 2001. During this period the site received 107 cm (42 in) of rainfall compared to the normal 132 cm (52 in). This amount was less than normal due to a severe drought.

Water Quality

When conducting this study there were several water quality parameters that were more important to the overall health of the ponds and ultimately the Tampa Bay estuary. The water quality parameters measured that were of significant value are shown in (Figure 2).

Nitrogen is an important nutrient for plants, but too much leads to noxious plant growth and blue-green algae blooms (Fox and Absher 2002). Nitrogen sources include fertilizers, atmospheric fallout, discharges from automobiles, mineralization of soil organic matter and decomposition of plant material (Rushton et al. 2002). A major pathway for both the ammonia and nitrate found in rainfall comes from the transformation of nitrogen oxides discharged from power plants and automobile exhausts.

All of the samples from the Street Pond were found to be over the established detection limit 0.01 mg/L of Nitrogen (Figure 2). This included the rainfall, inflow, outflow and the underdrain. It was found that the pond reduced the total nitrogen concentrations measured at the inflow by about 0.25 mg/L when measured at the outflow weir.

Even though nitrogen levels at the outflow of the pond did not exceed levels thought to produce nuisance algae blooms, the Street Pond was highly eutrophic as measured by the amount of nuisance plant growth and by the response of dissolved oxygen and pH (to be discussed later). This indicates that the level of inorganic nitrogen needs to be kept much lower than 0.3 mg/L to maintain ecosystem integrity. Nitrogen levels are a major concern in the region because nitrogen has been identified as the limiting factor in Tampa Bay.

Phosphorus concentrations are a concern in stormwater ponds because algae require only small amounts of this nutrient to live, excess amounts can lead to extensive algal blooms. (Fox and Absher 2002). Phosphorus is not a significant constituent in rainfall and is usually introduced into stormwater through soil erosion, construction activities, fertilizers and vegetation cycling. The U. S. EPA recommended a limit for phosphorus in streams and rivers of 0.1 mg/L (U.S.EPA 1986) and the values in the Street Pond met this criterion in the treated outflow (Figure 2). The median values for the underdrain discharge exceeded this value both for ortho and total phosphorus. Other studies have also found higher levels of inorganic nitrogen and phosphorus in the underdrain pipes of effluent filtration systems. Harper and Herr (1993) observed that concentrations of both ammonia and nitrate increased substantially during migration through the filter media at the DeBary detention with filtrations site. They also found increases of over 200% for outflow concentrations of ortho-phosphorus through the filter media. Trapped organic particles of N and P on the filter media were listed as probable causes.
Copper and Lead are a concern in urban runoff with loadings 10 to 100 times greater than the concentration of sanitary sewage (U.S.EPA 1983). Stormwater carries lead deposited on streets and parking lots from car exhaust, copper worn from metal plating and brake linings (Fox and Absher 2002). At the inflow, copper and lead were measured at higher concentrations than the outflow (Figure 2). The median concentrations for copper at the outflow were near the laboratory detection limit of 2.0 ug/L while the median values for lead were below the detection limit. This demonstrates that the ponds were effective in treating copper and lead before exiting the system. For this year of study, the pond discharge waters only exceeded the metal standards five times in the 180 samples collected.

Figure 2. Water quality parameters collected in the Street Pond inflow and outflow. Data obtained by composite sampling methods.
Field Parameters

Physical water quality parameters are important in understanding the processes that influence constituent cycling in natural waters. During this study, conductivity, dissolved oxygen (DO), pH, and temperature were periodically measured at the inflow and outflow with a Hydrolab Datasonde® 3 (Figure 3).

**Conductivity** - The graph for conductivity demonstrates the response of the pond to rainfall. During dry periods conductivity rose as evaporation occurred and the process concentrated ions. Rainfall diluted the water in the pond during rain events, which could be seen by a drop in the curve. As evaporation occurred between rainstorms conductivity began to increase again until the next event. The outflow conductivity exhibits a relatively unchanging pattern, showing that the ponds were effective in keeping the discharge conductivity steady.

**Dissolved oxygen** – Dissolved Oxygen was at low levels as it was discharged from the urban street drain, a level that was increased with rainfall. Dissolved oxygen at the outflow exhibited the wide fluctuations typical of a highly productive (eutrophic) phytoplankton dominated system (Figure 3). The algal process raised values of dissolved oxygen during the day and lowered concentrations during the night as the outflow demonstrates. This created a diurnal cycle and was the result of photosynthesis, which utilizes carbon dioxide and produces oxygen during the day while during nighttime hours, photosynthesis was absent, and algal respiration dominates, using oxygen and expelling carbon dioxide. The measurements of dissolved oxygen at the inflow were accurate in showing that rainfall raises dissolved oxygen levels due to surface-air interface. The release of metals and phosphorus from the sediments when dissolved oxygen is low (reduced conditions) is one reason state standards require that dissolved oxygen shall not fall below 5.0 mg/L and that normal daily and seasonal fluctuations above these levels shall be maintained (Ch. 62-302 FAC).

**pH** – pH like dissolved oxygen, is the result of algal photosynthetic processes that peak during daylight hours and reaches a low at night when algal respiration dominates producing carbon dioxide and using oxygen. This explained not only the diurnal cycles but also the higher pH values in the Street Pond. Rain events changed this relationship slightly (Figure 3).

The pH is an important parameter since it affects the water chemistry and biology in stormwater ponds. For example, denitrifying bacteria operate best in the range $6.5 < \text{pH} < 7.5$, while nitrifiers prefer $\text{pH} > 7.2$ (Kadlec and Knight 1996). This target range for denitrification was seldom reached in the Street Pond. Some chemical reactions also require pH at lower levels than found in the Street Pond. For example, aluminum phosphate precipitates best at a theoretical pH of 6.3 and iron phosphate at pH 5.3 (Kadlec and Knight 1996). The state of Florida Class III water quality standards permit a pH range between 5 and 8 standard units. This range was sometimes exceeded during daylight hours during the summer.
Figure 3. Inflow and outflow parameters measured in the Street Pond during 10 days in July 2001 with several rain events.
Flow data were analyzed to provide a better understanding of the how water quality loads affected the whole pond system. A complete water budget was estimated for one storm event that took place on July 23, 2001 (Figure 4). The inflow to the pond increased as the rainfall continued in intensity. The pond was then balanced by a volume of outflow that was close to the volume of inflow. The outflow was most likely due to pre-existing water in the pond, which was discharged as stormwater entered the system. The underdrain flowed continuously, which was possibly due to ground water but increases slightly during rain events. As the pond level increased and flowed into the underdrain, a small change could be seen as the water filled up volume in the pipe. One important note is that the underdrain flowed continuously and this data only represents an 8-hour storm. This discharge, although small on a daily basis, could be considerable when calculated as a monthly discharge. This is especially true for ammonia and nitrate, which were discharged at higher concentrations from the underdrain.
CONCLUSIONS

The effluent filtration system was effective in protecting the Tampa Bay estuary by acting as a “holding” pond allowing time for the pollutants to settle out of the water column and for biological processes to take place. The inflow to the Street Pond measured high levels of metals and soluble nutrients. The underdrain pipe showed considerably lower levels of metals, but like the inflow it also measured high concentrations of soluble nutrients. Concentrations of nutrients discharged over the weir were low in the Street Pond.

It was found that there was relatively no change in conductivity from the inflow to outflow in the Street Pond. There were improvements in dissolved oxygen at the outflow, which was accredited to algal processes.

It was concluded that the volume of inflow to the pond was nearly equal to the outflow of the system for most large rain events. From further study of smaller storms, it was shown that inflow volumes were greater than outflow volumes. According to the concentration levels during the July storm, it appears that the outflow volume measured was water that had been treated in the pond prior to the rain event.

Recommendations for pond improvements include:

• Plant the littoral zone with appropriate wetland plants.

• Clean out the side bank filter system and determine if this will solve the nutrient problem in the underdrains.

• Provide some pre-treatment to reduce metals and oils and greases.

• Clean out the initial sedimentation concrete lined basin on a regular basis to remove pollutants.

• Reuse the water in the pond to irrigate garden areas near the pond.

• Stock the pond with appropriate fish and other aquatic animals to determine if it can be maintained as a healthy aquatic habitat.

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LITERATURE CITED


