STORMWATER RESEARCH

Summary of Research Projects 1989 - 2002

Resource Management Department
Environmental Section

Southwest Florida Water Management District
Stormwater Research
at the Southwest Florida Water Management District

Summary of Projects
1989 - 2002

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EXECUTIVE SUMMARY

Introduction

Stormwater research at the Southwest Florida Water Management District (District) was initiated in mid-1988 in response to changing national and state laws requiring the District to implement non-point source pollution control technology. The cost of the research has been shared by grants from the Environmental Protection Agency (EPA) through the Florida Department of Environmental Protection (DEP), the Surface Water Improvement and Management (SWIM) program, and local governments through the District's Cooperative Funding Program. The data collected are used to evaluate the effectiveness of stormwater best management practices recommended by District rules, monitor the effectiveness of some SWIM projects, suggest water quality treatment methods to the District's Comprehensive Watershed Management (CWM) plans, and provide data for potential rule modifications, treatment systems, models, and retrofits. Finally, biennial stormwater conferences sponsored by the District's stormwater program provide for sharing of data with the regulated public, other agencies, and private consultants.

Since the inception of the research, twenty projects have been initiated (sixteen completed) to investigate stormwater pollution issues including: the efficiency of wet detention ponds and wetlands for water quality improvement, alum injection for pollutant removal, agricultural impacts to receiving waters, removal of bacteria by stormwater systems, mosquito problems in stormwater systems, reuse of stormwater, a comparison of constructed and natural wetlands used for stormwater treatment and the impact of aerial deposition on stormwater pollution. In addition, studies recently completed provide data and recommendations about: improvements in parking lot designs, pollution reduction by swales, and treatment ponds for agricultural runoff.

Content of Project Report Summaries

This summary of reports describes the types of research undertaken by the District and a bibliography of the project reports that have resulted from the research. Brief descriptions of each project are included and should provide the information necessary to determine if the complete report might be useful in your application. The findings contained in the project reports have been widely used by professionals who are interested in stormwater or watershed management when they need information such as: water quality data, efficiencies of stormwater technologies, loading rates, or innovative methods to improve stormwater runoff quality and quantity. In addition, data for some of the completed studies have been entered into an international data base and can be downloaded directly from the internet at www.bmpdatabase.org. Copies of the completed reports are available by calling the District headquarters in Brooksville at telephone number (352) 796-7211 ext. 4276 (Dr. Betty Rushton).
INTRODUCTION

This introductory chapter presents a brief overview of the Southwest Florida Water Management District, a historical perspective of District stormwater research, an indication of how the stormwater program fits into other District programs, a map with locations of projects including a brief project description, a table outlining applications of each project results, and status of the District projects. A table outlining funding sources and possible applications of the research results provides concise information. More complete results and conclusions are listed in the summaries of each project. A glossary gives definition of terms often used by environmental professionals.

District Overview

The District is one of five regional agencies that was established by the State Legislature to manage water and water-related resources of Florida. The District's responsibilities have expanded over the years in response to a growing need for a more comprehensive approach to water management. Areas of responsibility now encompass water supply, flood protection, water quality management and natural systems management. The stormwater research program was established to supply data and make recommendations to improve water quality discharged after storm events. The purpose is to provide information to help protect our region's rivers, lakes and estuaries.

Historical Perspective

Stormwater management is recognized as a practical method to improve water quality from non-point source pollution (i.e. pollution that runs off of our farms and neighborhoods after rain events). Initially stormwater was considered a water quantity problem solved by rapidly draining runoff into storm sewers, ditches or directly into lakes and rivers. By the mid-1970s studies showed over half the pollutant load entering Florida waters came from non-point source runoff. Serious efforts to control water quality degradation through point source control were initiated under the Federal Clean Water Act in 1972. Later revisions, known as the Water Quality Act of 1987, emphasized non-point source pollution. In 1972, the Florida Legislature enacted legislation which greatly expanded the responsibilities of the Water Management Districts from flood control to a full range of water management activities. To meet these new responsibilities, rules were written for the Management and Storage of Surface Waters (MSSW) for new developments (40D-4) in 1984. The Surface Water Improvement and Management (SWIM) legislation was passed in 1987 to implement plans and programs to improve habitat and water quality discharged into water bodies of state significance. More recently, local governments have been mandated to improve non-point source pollution loads through Federal National Pollutant Discharge Elimination System (NPDES) permits. Additionally, data are needed to develop Total Maximum Daily Loads (TMDL) for watersheds that are to be implemented using existing federal, state and local authorities.
**Purpose of the Stormwater Research Program**

Stormwater research at the District is designed to provide data to achieve multiple objectives to: (1) support or modify our rules under 40D-4, (2) monitor the pollution reduction achieved by some SWIM projects, (3) quantify the efficiency achieved by stormwater best management practices, (4) provide data and advice for stormwater improvement initiatives such as the Tampa Bay Estuary program, and (5) assist local governments with their own stormwater improvement programs through implementation of best management practices. The District program is also part of a coordinated statewide effort to determine effective cost efficient treatment of stormwater runoff. As part of this effort, the District sponsors biennial stormwater research and watershed management conferences, which are attended by over 250 professionals interested in water quality issues. Additionally, data from District projects are being incorporated into an international data base sponsored by the American Society of Civil Engineers through an Environmental Protection Agency grant. This will make comparable stormwater data available from throughout the world.

**Research Studies**

Figure 1 is a map showing the various project site locations and a legend with the project’s current status. Following Figure 1 are summaries of each project with symbols that match the site location on Figure 1. Table 1 provides a list of the projects and their funding source as well as a brief description of the most pertinent conclusions and applications. Following Table 1 are individual project summaries that provide more complete details of the research as well as the conclusions/recommendations that resulted from the study.

Studies generally fall into two categories. Surveys of a large number of stormwater systems permitted by the District were conducted to determine how well our rules met state of Florida water quality objectives. In these studies grab samples were collected after rain events to compare to State standard. For the in-depth studies, automatic equipment was installed to collect flow-weighted samples. For these studies, which usually were conducted for at least a two year period, analyses also included rainfall data, water table measurements, sediment constituents and vegetation characteristics. Other studies added information about bacteria and mosquitoes in stormwater systems.

**Cooperative Funding Grants**

Another source for adding to our stormwater data-base and achieving water quality goals are the District’s cooperative funding grants. This cooperative funding helps local governments meet new challenges which have been intensified because of the impact of current federal, state and local legislation. Some of the reasons for needing more data are the establishment of stormwater utilities, the NPDES program and problems associated with redevelopment in urban areas. The District’s Cooperative Funding program provides a mechanism for receiving matching funds
for worthwhile projects. Starting in December of each year, basin boards begin the process of selecting worthwhile proposals submitted by local governments and other public or private entities. The Basin Boards share the cost of those projects selected. These proposals are usually generated in response to priorities listed in the Comprehensive Watershed Management plans for each basin. A workshop held in November of each year is a desirable pre-requisite for guidelines about how to proceed in submitting proposals. For more information contact the appropriate Governmental Affairs Coordinator based in their representative counties.

Rand R. Baldwin  
**Hillsborough, Pinellas and Pasco**  
(813) 985-7481

Jimmy A. Brooks  
**Citrus, Hernando, Lake, Levy, Marion and Sumter**  
(352) 527-8131

Joanne L. McClellan  
**Hardee, Highlands, and Polk**  
(941) 534-1448

Steven A. Minnis  
**Charlotte, DeSoto, Manatee, and Sarasota**  
(941) 486-1212
Figure 1. Project locations
STORMWATER RESEARCH PROJECTS
The symbol for each project corresponds to the legend on the site location map.

Completed Projects

Surveys

- Water Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds

Grab samples taken within one to two days after rain events from effluent discharges of permitted wet-detention ponds found some exceedences (non compliance) of State water quality standards. Data were also analyzed for seasonal and flow related patterns. In addition, multivariate statistical analysis looked at relationships between constituents as well as hydrological parameters.

¶ Outfall Water Quality from Wet Detention Systems

This study focused on storm water quality from permitted stormwater systems before and after discharge over an outfall weir. Water quality from both constructed and natural detention ponds were compared to State standards for compliance. Relationships between variables were analyzed with statistical correlations. No statistical differences were found between water quality on either side of the weir during discharge (except pH and dissolved oxygen), thus representative samples can be collected from the more accessible pond side.

A Survey of Water Quality of Wetlands-Treatment Stormwater Ponds

A water-quality survey of stormwater treatment systems that employed existing wetlands and including constructed pre-treatment sedimentation basins was conducted. The survey provided regional stormwater data, and documentation of exceedence of State water-quality standards at points of discharge from permitted wetlands- treatment systems. Additionally, statistical analysis of relationships among survey variables provided insight about factors that affect water quality.

± A Survey of Outflow Water Quality from Detention Ponds in Agriculture

This study tested outflow water quality for compliance with State water quality standards. Although exceedences (non-compliance) of water quality standards were detected, the violations were infrequent. The only parameter that alerts caution is low dissolved oxygen levels detected at almost all sites. Comparisons to similar data from other studies are included. Since most of these ponds discharged continuously samples were collected on a monthly basis and do not represent stormwater runoff.
In-depth Studies

- Integrating a Herbaceous Wetland into Stormwater Management

An analysis of 81 storm events during a 30 month period established an extensive water quality and hydrologic data base for a wetland used for stormwater treatment. This report also includes sections on sediment quality and vegetation analysis. Other sections looked at relationships between variables, the first flush effect, a hydrologic water budget, and continuous measurements of dissolved oxygen, pH, conductivity and other field parameters.

- An In-Depth Analysis of a Wet Detention Stormwater System

Flow-weighted samples collected at the inflow and outflow showed the study pond removed pollutants by 30 to 60 percent for most constituents. Rainfall directly on the pond was a significant input for inorganic nitrogen and some metals. The wet detention pond was shown to be effective as a settling basin, but a better design with a longer detention time was recommended.

- Three Design Alternatives for Stormwater Detention Ponds

The wet detention pond described in the study above (An In-Depth Analysis of a Wet Detention Stormwater System) was reconfigured in three different retention designs. The best design included a 14-day residence time where most constituents were reduced by at least 80%. The exceptions were organic nitrogen and ammonia. All samples met State water quality standards for metals at the outflow.

- An Assessment of an In-Line Alum Injection Facility Used to Treat Stormwater Runoff in Pinellas County, Florida

Pre- and post- alum treated storm event water quality and flow data were collected and load reductions calculated. Comparisons to water quality standards were performed, monthly downstream water quality samples were collected, and the toxicity of aluminum in the environment was discussed. The important role that operation and maintenance played in the treatment effectiveness was also evaluated.

- Removal of Microbial Indicators from Stormwater Best Management Practices

In this study, indicators and surrogates of microbial pathogens were used to determine how well three types of stormwater systems reduced microbes using simulated storm events. The three types of systems were: sand filtration, wet detention and alum coagulation. Samples were taken before the introduction of the surrogate or indicator organisms, right after the introduction and then ten samples at timed intervals. Heavy metals, turbidity and total suspended solids were also measured using the same experimental design. Significant reductions (p<0.05) in total and fecal coliform bacteria,
MS2, and bead concentrations were usually observed for all systems, but sometimes greater concentrations were measured in outflow samples than in inflow samples.

**Control of Mosquito Breeding in Permitted Stormwater Systems**

One hundred and thirty-eight SWFWMD permitted stormwater projects which included 238 individual stormwater systems in Sarasota county were selected for study. Systems were divided into permanently flooded and intermittently flooded. The project sites were tested for mosquito breeding. Also, materials classified as traditional insecticide (Abate), oil formulation (Golden Bear), biological ( VectoBac) and a growth regulator (Altosid) were used against natural larval populations. Intermittently flooded systems produced the most mosquitoes.

**Florida Aquarium Parking Lot: A Treatment Train Approach**

This project examined basin-wide treatment for stormwater management. Flow measurements and water quality samples were collected for rain events to calculate volume and pollutant reductions from three pavement types (asphalt, concrete, and porous). Also evaluated were the pollutant reductions provided by swales between parking rows, a cypress strand and a small wet detention pond used for final treatment. Additionally, the monitoring effort investigated other processes taking place by measuring pollutants in rainfall and sediments as well as variations in pH, dissolved oxygen, temperature, conductivity, and redox in the pond. Most of the storm runoff was retained on site and during the year it was monitored the pond discharged off-site only once. The swales in the parking lot reduced runoff from 50% to 30% and porous paving reduced it from 50% to 17%.

**Treatment of Stormwater Runoff from an Agricultural Basin (Phase I)**

This project assessed the effects of a wet-detention pond on the water quality of stormwater runoff from an agricultural watershed. Monitoring included flow-weighted samples collected at the inflow and outflow to the detention ponds, as well as collection of rainwater for chemical analysis. Other monitoring efforts included bi-weekly measurements of the water table and quarterly ambient monitoring of water in the pre-treatment ditch, three sediment sampling events for the entire stormwater system, and water quality monitoring in the wells. During the three years of data collected during phase I (70 rain events) over 65% of all pollutant loads for potentially toxic metals entered the pond during five “El Nino” storms.

**Ongoing Studies**
Wetland Hydrology

In this study the hydrologic effects of a borrow pit built adjacent to six forested wetlands is being investigated. Data collection includes recording bi-weekly surface water and surficial groundwater levels, conducting detailed vegetation analyses each spring and fall, and performing quarterly surface water quality sampling.

Stormwater Alternatives: Demonstration Project

A monitoring program is designed to measure pollutant loads discharged to the bay from two different types of stormwater ponds – an effluent filtration wet pond and an altered wet detention pond. This data will also be compared to a low impact parking lot design located on site. In addition, the effluent filtration system is being monitored to provide data for the entire pond system including flow-weighted samples at the inflow, outflow and under-drain pipe as well as rainfall directly on the pond. Other stormwater alternatives are being investigated through a literature search and a summary of each method will be compiled for use by other environmental professionals. A few of these alternatives will be implemented at the site and the results quantified.

Treatment of Stormwater Runoff from an Agricultural Basin - Phase II

This project is a continuation of the Cockroach Bay (phase I) study described above. The final report will provide a continuous record for four years during all seasons and includes both the worst drought on record as well as floods from the “El Nino” storms to compare to more normal rainfall years. The data will be used to calculate loading rates and will more thoroughly document the efficiency of the wet detention pond in reducing agricultural pollutants. Since field investigations involving agricultural runoff from row crops is limited, the data will provide support for stormwater runoff guidelines and could be one of the first steps to determine a total daily maximum load (TMDL) for Tampa Bay.

Broadway Outfall CDS Unit and Constructed Wetland

A SWIM retrofit project has installed a Continuous Deflection Separation (CDS) unit and a constructed wetland that will be monitored for a two-year period. Composite flow-weighted samples will be collected before stormwater enters the system, after it leaves the CDS unit and again as it exits the wetland. Rainfall water quality and quantity will also be measured as well as water levels. Pollutants in the sediments will be measured before the modifications, after the modifications and again at the end of the monitoring effort. Macroinvertebrate sampling is also part of the data collection.
Table 1. A list of District stormwater research projects and the application of results.

<table>
<thead>
<tr>
<th>PROJECT NAME</th>
<th>FUNDING SOURCE</th>
<th>APPLICATION</th>
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</thead>
</table>
| Water-Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds | District - $100,000 | 1. Documented effectiveness of MSSW Rule.  
2. Identified seasonal effects & problem pollutants.  
3. Found from 3% to 39% non-compliance of state WQ standards.  
4. Documented more WQ non-compliance with greater imperviousness. |
| In-Depth Analysis of a Wet Detention Stormwater System | District - $120,000 | 1. Documented deficiencies in design esp. dissolved oxygen, mosquitoes.  
2. Made recommendations for improvements including longer residence time.  
3. Documented pollution from rainfall esp. inorganic nitrogen & some metals.  
4. Identified problem pollutants in discharge water - Dissolved oxygen, some metals. |
| Integrating a Herbaceous Wetland into Stormwater Management | EPA - $55,000  
District - $55,000 | 1. Identified changes when an oligotrophic marsh is used for stormwater treatment.  
2. Documented exceedence of std. for copper, lead and zinc 4% to 40% of samples.  
3. Found zinc in west basin sediments at toxic levels indicating the need for maintenance.  
4. Showed alteration of shoreline promoted growth of nuisance plant species.  
5. Documented retention of water by the marsh and ET improved removal efficiencies.  
6. Showed pre-treatment basins reduced pollutant loads to the marsh but were not sufficient to reduce pollutant loads below toxic levels. |
| Control of Mosquito Breeding in Permitted Stormwater Systems | Sarasota Co. Mosquito Control - $20,000  
Manasota Basin - $20,000 | 1. Found dry effluent filtration systems often create serious mosquito problems.  
2. Documented organic matter in systems produced more mosquitoes (grass clippings,etc)  
3. Found maintenance of structures and sediment build up a problem - needs monitoring often.  
4. Recommended minnow sumps and stocking mosquito fish in stormwater systems.  
5. Need a method to track the 1000s of stormwater systems - GIS, etc. |
| Mosquito Prevention in Stormwater Systems | Sarasota Co. Mosquito Control - $5,000  
Manasota Basin - $5,000 | 1. Developed a brochure suitable for the general public, incl. maintenance & other ideas.  
2. Provided a maintenance example of how to recontour pond to reduce mosquito problems.  
3. Identified cattail, water hyacinths and water lettuce as the most troublesome plants for sheltering mosquito larvae. |
Table 1. (Continued)

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<thead>
<tr>
<th>PROJECT NAME</th>
<th>FUNDING SOURCE</th>
<th>APPLICATION</th>
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<tbody>
<tr>
<td>Stormwater Reuse, Design Curves for SWFWMD</td>
<td>District - $20,000</td>
<td>1. Developed REV (Rate-Efficiency-Volume) charts to use to calculate reuse benefits.</td>
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<td>2. Demonstrated stormwater reuse can be used to meet 80% pollutant removal goal.</td>
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<td>3. Based on actual rainfall record of the region.</td>
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<tr>
<td>Comparative Water Quality Data of a Deep and Shallow Wet Detention Pond</td>
<td>District - $40,000</td>
<td>1. Documented that shallow pond (3 feet deep) had better removal rates than deep pond (9 feet deep).</td>
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<td>2. Demonstrated stratification in the deep pond but not in shallow pond.</td>
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<td>Wetlands-Treatment Stormwater Ponds</td>
<td>District - $50,000</td>
<td>1. Documented that up to 38% of discharging samples failed to meet WQ stds for metals.</td>
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<td>2. Identified low dissolved oxygen as a possible culprit.</td>
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<td>3. Found dissolved oxygen in non-compliance &gt; 50% of samples.</td>
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<td>A Survey of Outflow Water Quality from Detention Ponds in Agriculture</td>
<td>District - $50,000</td>
<td>1. Documented that WQ better than from untreated agricultural discharge.</td>
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<td>2. Showed non-compliance with WQ stds. for DO, lead, iron, and pH at several sites.</td>
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<td>3. Found nutrient values below literature values for other treated agricultural runoff.</td>
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<tr>
<td>Three Design Alternatives for Stormwater Detention Ponds</td>
<td>EPA - $50,000; District - $50,000</td>
<td>1. Found Conservation Wet Detention design met all state water quality standards.</td>
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<td>2. Documented 80% reduction for most pollutants - A State Water Policy goal.</td>
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<td>3. Showed problem with PAHs as ponds age.</td>
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<td>4. Identified the importance of entire drainage basin in reducing discharge.</td>
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<td>Outfall Water Quality from Wet Detention Systems</td>
<td>District - $60,000</td>
<td>1. Documented constructed wet detention better than natural wetlands.</td>
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<td>2. Found dissolved oxygen in non-compliance &gt; 50% of samples.</td>
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<td>3. Samples collected in front of outfall structure reliable for comparison to State Standards</td>
</tr>
<tr>
<td>Alum Injection for Stormwater Treatment - Pinellas Park</td>
<td>District - $60,000; SWIM - $249,115 (used for construction of site)</td>
<td>1. Documented a need for strict operation and maintenance guidelines for alum treatment.</td>
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<td>2. Alum injection effective for removing phosphorous.</td>
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<tr>
<td>PROJECT NAME</td>
<td>FUNDING SOURCE</td>
<td>APPLICATION</td>
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<tr>
<td>Assess Agricultural Best Management Practice Discharging to Cockroach Bay</td>
<td>EPA - $155,407 District - $103,604</td>
<td>1. Pervious drainage basin and pre-treatment ditch reduced rainy season runoff to 30% 2. About 25% of all storm input to the pond was contributed by rainfall directly on pond 3. Water quality loads were reduced by &gt; 60%, but rainfall patterns affected this 4. Of the ten pesticides detected at the inflow only four were detected at outflow. 5. Phosphorus was measured at relatively high concentrations at inflow (avg &gt; 1 mg/L) 6. Metals in sediments greatly increased after fresh water exits pond into salt water marsh.</td>
</tr>
<tr>
<td>A Treatment Train Approach for Stormwater Management</td>
<td>EPA - $196,996 District - $131,331</td>
<td>1. Found parking lot design extremely effective in reducing amount of runoff. 2. Reduced runoff meant no pollutant discharge to Tampa Bay - The best strategy. 3. Swales reduced runoff from 50% to 30% and for porous paving to 17%. 4. Larger garden areas reduced runoff by another 50%. 5. Identified air pollution as significant source of stormwater pollution. 6. Documented treatment by swales and strands.</td>
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<tr>
<td>Removal of Microbial Indicators from Stormwater BMPs</td>
<td>District - $ 45,000</td>
<td>1. Disease causing bacteria found at inflow and outflow. 2. Systems usually reduced bacteria 3. Determined that a treatment train system would work best to treat bacteria. 4. Chlorine disinfection, ozonation, and UV light irradiation could help treat stormwater</td>
</tr>
<tr>
<td>Wetland Hydrology Pre- and Post Development</td>
<td>District - $ 17,398</td>
<td>1. Determine if wet detention pond/borrow pits dewater wetlands. 2. Document before and after effects of development on natural wetlands.</td>
</tr>
<tr>
<td>Stormwater Management Alternatives Demonstration</td>
<td>EPA - $181,575 District - $121,506</td>
<td>1. Ponds with algae problems need remedial solutions other than copper treatment. 2. Fish and other aquatic species stocked in ponds may provide benefits. 3. Found highest concentrations of nutrients in under drains. 4. Found maintenance of ponds the most critical problem.</td>
</tr>
<tr>
<td>BMP Data Transfer Grant</td>
<td>ASCE/EPA - $9,500</td>
<td>1. EPA grant paid for entering our data into an international data base available on the internet. 2. Data for over 100 stormwater studies available at <a href="http://www.bmpdatabase.org">www.bmpdatabase.org</a>.</td>
</tr>
<tr>
<td>Project</td>
<td>EPA</td>
<td>District</td>
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<tr>
<td>Cockroach Bay (phase II)</td>
<td>$77,455</td>
<td>$51,647</td>
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<tr>
<td>Broadway Outfall Monitoring</td>
<td>$162,550</td>
<td>$108,374</td>
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Water-Quality Survey of Twenty-Four Stormwater Wet-Detention Ponds

Author(s): Mark J. Kehoe
Year Completed: 1993
Project Costs: District-$100,000

Project Rationale:

As part of its stormwater management responsibility, the Southwest Florida Water Management District conducts research to implement better stormwater regulations. During 1988-89, the District conducted a water-quality survey of twenty-four stormwater wet-detention ponds that had been permitted by the District in the Tampa Bay Region. These ponds were studied to characterize the discharge effluent water quality and to determine consistency with State water quality standards.

Project Description:

The objectives of the survey were threefold: (1) to provide regional, base-line water-quality data in urban, stormwater wet-detention ponds, (2) to document whether the water quality of effluents from wet-detention ponds met State water-quality standards, and (3) to explore relationships among physical/chemical (water-quality) variables, water-level variables, and pond dimension variables. To accomplish the objectives, grab samples were collected in the pond and at the outflow within two days after a storm event.

Project Results:

- Samples collected at the outfall station (located at the point of discharge from wet-detention ponds) found exceedences (non compliance) of State water quality standards which included: dissolved oxygen (34%), zinc (31%), cadmium (10%), copper (12%), lead (9%), conductivity (6%), turbidity (3%), chromium (3%), nickel (1%) and magnesium (1%).

- Exceedence of the total suspended solids standard (20 mg/L -- for an efficient secondary sewage treatment) in 10 percent of samples, and exceedence of the turbidity standard (29 NTU) in only 4 percent of samples indicated the wet-detention ponds were effective as sedimentation basins.

- Evaluation of seasonal patterns in the data indicated that hydrologic conditions (i.e., water levels) were rainfall related, as expected. More importantly, several variables (conductivity, turbidity, cadmium, and possibly zinc and iron) were inversely correlated with rainfall-related water-level indicators (i.e., the number or percent of ponds discharging, and the bottom depth at the sample location). Also, as would be expected seasonal temperature patterns were important with regards to dissolved oxygen levels.
• The inverse relationship between the number of ponds discharging and mean outfall-station concentrations for certain water-quality variables also suggests that higher mean values and perhaps more exceedences of standards corresponded with periods of lower rainfall when fewer ponds were discharging. Thus, an exceedence during dry periods might not actually constitute a violation of water quality standards since these are designed to protect receiving waters.

• Results of multivariate statistical analyses (cluster techniques, multiple regressions, etc.) provided evidence that hydrologic conditions and pond dimensions were important for certain water-quality variables, especially suspended particles and iron. The results also suggested a relationship between water quality and primary production in wet-detention ponds since temperature, dissolved oxygen and pH were closely related.

• Data from the land-use evaluations and cluster analyses of ponds suggested that multi-family residential ponds are among those with poorest water-quality, probably caused by greater impervious areas.

**Project Conclusions:**

• Some additional parameters should be incorporated for more complete evaluation of water-quality data (e.g., total hardness, alkalinity, redox potential, nutrients and/or chlorophyll, and color). These variables are important because of their influence on metal concentrations and metal toxicity, as well as, on other water-quality characteristics.

• Research concerning the ecological value of stormwater ponds has been mostly overlooked. With ever increasing development pressures reducing wetland and surface-water resources, biological sampling (e.g., plants, algae, and benthos) would help determined the strengths and weaknesses of stormwater ponds as fish and wildlife habitat.

• Stormwater rules should relate percent impervious area to the amount of treatment required for stormwater ponds since the greater the impervious area, the more often these stormwater systems exceed standards.

**District Report Reference:**

Stormwater Reuse, Design Curves for Southwest Florida Water Management District

Author(s): Tom J. Harrison  Year Completed: 1993  Project Costs: District $20,000

Project Rationale:
Investigations have shown that wet-detention practices with longer residence times increase pollution removal efficiencies. An alternative method of improving treatment efficiency is proposed by reducing the quantity of stormwater discharged from the pond by implementing a reuse component. Reuse conservation benefits include conservation of rainfall runoff, reduced demand for potable water for irrigation, and enhanced groundwater recharge.

Project Description:
This study developed rate-efficiency-volume (REV) charts for six rainfall stations within the District, analyzed the impact the length of the rainfall record has on the average annual removal efficiency, and compared the average annual removal efficiency for the period of record to annual and seasonal removal efficiency.

Project Results:
- The REV charts developed in this study serve as design aids to determine the relation between the reuse volume, the reuse rate, and the percent of the average annual runoff which can be expected to be reused.
- Demonstrated that stormwater reuse can be used to meet 80% pollutant removal goal.

Project Conclusions:
- The reuse of stormwater runoff can help meet irrigation demands, increase groundwater recharge and improve the quality of surface water runoff.
- The reuse potential of stormwater is limited only by the creativity of the design engineer to capture runoff.
- The stormwater reuse rate is not a guaranteed supply therefore other water sources are necessary to meet specific needs.

District Report Reference:
Harrison, T.J. 1993. Stormwater Reuse Design Curves for Southwest Florida Water
Management District. *In* Proceedings of the 3rd Biennial Stormwater Research Conference. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609.
Comparative Water Quality Data of a Deep and a Shallow Wet-Detention Pond

Author(s): Jeffery Cunningham  
Year Completed: 1993  
Project Costs: District $40,000

Project Rationale:
Stormwater treatment criteria as stated in State Water Policy 62-40 has a goal of 80% removal efficiencies for annual pollutant loads. A common method used to treat stormwater includes wet-detention. Studies have indicated that some wet-detention systems fail to meet the goal of 80% removal. As a result, this study investigated methods to improve the wet-detention system design.

Project Description:
This study examined the effect of the depth of the permanent pool on pollutant removal efficiency. Two adjacent ponds with similar parameters except for the depth (9.0 feet vs. 3.5 feet) were tested for pollutant removal. Pollutant removal efficiencies were calculated based on mass loading numbers.

Project Results:
- Removal efficiencies for copper were low in both ponds, possibly due to low concentrations entering at the inflow. The highest removal efficiencies for both ponds was for iron. Iron removal was 87% for the deep pond and 85% for the shallow pond. Since iron removal is a good predictor for the behavior of other metals, it can be assumed that efficiencies for copper and zinc would have been better if concentrations had been higher.
- Suspended solid and volatile suspended solid removal was greater in the deeper pond (77% vs 69%).
- Nitrogen removal was modest (<50%) in both ponds. Greater than 80% removal for ortho-phosphorous was recorded for both ponds.
- Low dissolved oxygen levels at the bottom of ponds were associated with thermal stratification. The deeper pond was stratified more often than the shallow pond.

Project Conclusions:
- The removal efficiencies between the two ponds were similar except for greater suspended solid removal in the deeper pond.
• Wet-detention pond depth does not seem to significantly affect removal efficiencies of nutrients and metals, but low initial concentrations of metals may have skewed this result.
• Deeper ponds may be more prone to low dissolved oxygen levels at the bottom due to increased frequency of thermal stratification.

District Report Reference:

Control of Mosquito Breeding in Permitted Stormwater Systems

Author(s): Frederick J. Santana, John R. Wood, Ray E. Parsons and Sally K. Chamberlain
Year Completed: 1994
Project Costs: Sarasota County Mosquito Control - $20,000/ Manasota Basin - $20,000

Project Rationale:

Three common stormwater system types in Sarasota County are wet detention, effluent filtration and retention ponds. Between 1984 and 1994, approximately 2,600 systems were approved for construction in Sarasota County. This study was undertaken to gain an understanding of mosquito breeding in these systems and to document the measures needed to control them. The specific objectives were to determine: 1) the relative importance of detention, effluent filtration, and retention stormwater control facilities as mosquito breeding sites, 2) the major pest and disease vector species that utilize facilities for breeding, 3) the seasonal occurrence and abundance trends for dominant species, 4) the comparison of system type and age on production patterns, and 5) the efficacy of conventional larval control materials against natural populations of mosquitoes occurring in stormwater systems.

Project Description:

One hundred and thirty-eight stormwater projects permitted by SWFWMD (including 238 individual stormwater systems) were selected for study. Systems were divided into permanently flooded (PF) and intermittently flooded (IF). Collections of larval mosquitoes were made using a standard 350 ml mosquito dipper and each dipper collection taken is termed a sampling event. Approximately 12% of the permanently flooded systems were inspected for mosquito breeding biweekly. Another 15% were inspected monthly and the remaining 72% were inspected bimonthly. Inspections of intermittently flooded systems depended on rainfall. Both short and long-term (sustained-release) materials were tested against natural larval populations occurring in stormwater systems. Materials tested can be classified as a traditional insecticide (Abate), oil formulation (Golden Bear), biological (VectoBac) and a growth regulator (Altosid).

Project Results:

- The majority of PF systems did not produce large numbers of mosquitoes when compared to IF systems.

- One hundred and eighty-six (76%) of the 238 stormwater systems surveyed for mosquito breeding between June and August 1993 were mosquito productive. When only mosquito productive systems are considered, approximately 50% of the events from PF systems and 75% from IF systems were positive for mosquitoes. Larval densities of IF systems were also greater than for PF systems.
Twenty-one species of mosquitos were identified from larval collections including 12 nuisance pests and 3 disease vectors. Pest and vector species comprised 95% of the total number (45,555) of mosquitoes collected. IF systems produced the most mosquitoes.

The water retention characteristics of an intermittently flooded system determined its mosquito production potential. The majority of unproductive IF systems dried out within 3 days following significant rainfall. Generally, IF systems that retained water for more than 3 days were mosquito productive.

An important factor which influenced some species in IF systems was the amount of decaying organic matter present. Extremely large aggregations were observed in association with decaying organic matter. Decaying vegetation came from a variety of sources and was usually associated with maintenance practices such as chopping or herbiciding vegetation with subsequent breakdown and decay.

Short-term control materials Abate, Golden Bear and Vectobac provided between 91% - 100% control of existing larval infestations in IF systems 24 hour post treatment. The application of sustained-release materials to problem systems before the onset of the mosquito season reduces both their breeding potential and the time necessary for surveillance.

Project Conclusions:

Careful consideration should be made before IF stormwater systems are selected as the Best Management Practice (BMP) for handling stormwater. This BMP should only be implemented at sites which contain coarse-grained sandy soils and a minimum of 3 feet between the facility floor and the seasonal high water table level. Considering their mosquito production potential, this stormwater management method should be avoided whenever possible.

Systems should be kept free of excess organic matter. When the perimeter or floor of a basin is mowed, the clippings should be removed. If overgrown vegetation is killed, the dead plants should be removed.

Circumstances that restrict the flow of water from a system should be corrected. Debris or silt build-up interfering with an outfall structure should be removed. Underdrain and filtration media should be inspected periodically and cleaned out or replaced as needed.

The facility floors of IF systems and the littoral shelves of PF systems should not contain depressions that retain isolated pools of water.

Sustained-release larvicides should be used whenever possible. Known mosquito productive systems should be treated before the onset of the mosquito season.
• PF systems should be stocked with native mosquito fish to foster biological predation on mosquito larvae.

**District Report Reference:**

Mosquito Prevention in Stormwater Systems

**Author(s):** Sarasota County Mosquito Control District  
**Year Completed:** 1994  
**Project Costs:** Sarasota County Mosquito Control - $5,000/ Manasota Basin - $5,000

**Project Rationale:**
Using the study “Control of mosquito breeding in permitted stormwater systems” and the actual reconstruction of a stormwater pond, a brochure was developed to provide practical information to the public.

**Project Description:**
The brochure provided description of the problem, solutions to correct the problem, tips on maintenance for mosquito prevention, and some general information about stormwater systems.

**Project Results:**
An informative and useful brochure was developed with the cooperation of the District, Sarasota County Mosquito Control District, and Sarasota County Stormwater Environmental Utility. The brochure was written in easy-to-understand language for the general public. This brochure is available to any interested party for dissemination.

**Project Conclusions:**
- Designate responsibility for maintenance of stormwater systems.
- Avoid sediment buildup to prevent mosquito producing standing water.
- Avoid dumping grass clippings or organic debris into stormwater systems.
- Remove aquatic plants which nourish and shelter mosquito larvae. Replace troublesome plants with beneficial aquatic plants.
- Create “minnow sumps” in drought-sensitive stormwater ponds. Stock ponds with predatory “mosquitofish”

**District Report Reference:**
Brochure entitled “Mosquito Prevention in Stormwater Systems"
A Survey of the Water Quality of Wetlands-Treatment Stormwater Pond

Author(s): Mark J. Kehoe, Craig W. Dye, and Betty T. Rushton
Year Completed: 1994
Project Costs: District-$50,000

Project Rationale:

Wetlands are associated with the transition from upland to aquatic ecosystems and provide many natural amenities to society including flood control, water quality enhancement, and fish and wildlife habitat. Although surface runoff is a natural source of hydrologic inputs to wetlands and surface waters, non-point sources of pollution associated with human activities make stormwater runoff a major source of degradation of surface waters in Florida. This study investigated the ability of natural wetlands to treat stormwater without degrading the wetland while still meeting State water quality standards at the outflow.

Project Description:

A water-quality survey of stormwater treatment systems that employed wetlands-treatment with pre-treatment and natural wetlands was conducted. The survey provided regional stormwater data, and documented the exceedence of State water-quality standards at points of discharge from wetlands-treatment systems. Additionally, statistical analysis of relationships among survey variables provided insight about factors that affect water quality in wetlands-treatment systems.

Project Results:

- Total percent exceedence of water-quality standards at the twelve wetland outfalls focused attention on variables that frequently exceeded standards in the Wetlands-Treatment Survey (and also the Twenty-Four Pond Survey). Wetland treatment systems failed to meet standards while discharging for: dissolved oxygen 70%, cadmium 37%, zinc 27% and copper 2% of the time.

- The anaerobic characteristics of many wetlands may account for the fact that percent exceedence was much higher for dissolved oxygen and total cadmium in the Wetlands-Treatment survey than the exceedence for these parameters found in the 24 pond survey.

- In overall paired statistical comparisons, pre-treatment stations had greater average depths, temperature, dissolved oxygen, pH, total zinc, and copper than wetland outfalls, suggesting that natural wetlands are generally effective in reducing some constituents.

- Notable water-quality relationships observed during the survey suggest that an equilibrium between primary production (i.e., photosynthesis), aerobic (microbial) respiration, and temperature are responsible for temporal and spatial dissolved oxygen
distribution. Results also suggest that pH-mediated mechanisms and oxidation-reduction potential affect heavy metal concentrations.

- Numerous factors were probably involved in establishing ambient water quality at the two stations in the survey wetlands-treatment systems. There were indications of water quality variability between wetlands and of seasonal fluctuations in the data, a result that agrees with the variability noted in an earlier study of 24 wet-detention systems. The data suggest that hydrologic conditions may have a significant impact on constituent concentration and the roles of sediments in samples, internal sediment and biogeochemical cycles, plant and algal cycles, and rainfall and runoff sources of metals.

Project Conclusions:

- There is potential for both positive and negative impacts when using natural wetlands as part of a stormwater treatment system. Stormwater provides the hydrologic input that may be necessary to keep the wetland viable, but the stormwater it receives may change the character of the wetland. For example, pH and dissolved oxygen were measured at much lower concentrations in wetland water than in stormwater in the pre-treatment basin.

- Natural wetlands may not meet water quality standards as well as constructed wetlands. Dissolved oxygen, for example, was in non-compliance in the discharge water of natural wetlands 75 percent of the time compared to 40 percent, in constructed wetlands. The use of fountains in many constructed ponds likely caused this result.

- Some metals were also more problematic in natural wetlands. Toxic levels of cadmium exceeded standards in the discharge water 37 percent of the time compared to 10 percent in constructed ponds. For zinc exceedences were about the same (27% for natural vs. 31% in constructed).

- Other toxic pollutants were more common in constructed wetlands. Copper non-compliances were higher in constructed wetlands (2% for natural and 12% for constructed) probably caused by maintenance practices in constructed ponds. Lead never exceeded standards in natural wetlands but was measured at toxic levels 8 percent of the time in the discharge water of constructed ponds.

District Report Reference:

Integrating a Herbaceous Wetland into Stormwater Management

Author(s): David W. Carr and Betty T. Rushton
Year Completed: 1995
Project Costs: EPA-$55,000 / District-$55,000

Project Rationale:

The large number of natural wetlands and the rapid population growth in Florida make using existing isolated wetlands an attractive alternative for stormwater treatment. Uncertainty exists, however, in their ability to absorb the increased peak volumes and higher levels of pollutants found in urban runoff. This study evaluated the effectiveness of a marsh to treat stormwater, compared water quality results to State water quality standards and documented the effects of urban runoff on marsh vegetation and sediments.

Project Description:

This project incorporated an existing isolated wetland as part of a stormwater system at an office complex. The wetland was a 3 acre herbaceous marsh which had historically received most of its hydrologic input directly from rainfall and a small amount of runoff from surrounding native pine forests; therefore, it was characterized by low levels of nutrients, dissolved oxygen, pH and conductivity. After development, it also received hydrologic input from urban runoff (15.3 acres in an office park), which had received some pre-treatment from sedimentation basins. The 0.175 acre east sedimentation basin received its runoff from a central roadway and the 0.012 acre west basin collected runoff from a parking lot and a portion of an office building before discharging into the marsh. To study the effect of stormwater on the marsh, automatic data recording stations were installed to measure water quality and quantity as it was discharged from the sedimentation basins and again as it was discharged from the marsh. A rainfall station measured these parameters for rain. Analysis of 81 storm events during the 30 month study provided extensive water quality and hydrologic data.

Project Results:

- Removal efficiencies (i.e. the sum of pollutant load from rainfall and surface water inputs compared to pollutant loads at the outflow) indicate the marsh effectively reduced the following: cadmium by 92 percent, inorganic nitrogen, suspended solids and zinc by at least 85 percent, and copper and phosphorus by at least 71 percent. Removal efficiencies were good because only 27 percent of the water measured coming into the marsh was discharged, the rest was lost by evapotranspiration and infiltration.

- Marshes can be effective at removing stormwater pollutants, but changes in the physical and chemical properties of the marsh will occur. The sedimentation basins had significantly higher levels of pH, dissolved oxygen, oxidation reduction potential and
conductivity than was measured in the marsh but higher levels of these parameters were starting to be measured in the marsh by the end of the study.

- Event mean concentrations measured at the outflow exceeded State standards in effect after 1992 by the following percentages: Lead 62%, zinc 23%, copper 44%, and cadmium 2%. One reason for the high noncompliance were the result of the soft water that is typical of many natural wetlands. Soft water makes metals more toxic to organisms, therefore, the standard is hardness dependent and wetlands that receive much of their input from rainfall exceed standards more often for equal concentrations of metals.

- Rainfall was found to be a source of inorganic nitrogen and zinc to the marsh.

- Total annual rainfall on the marsh represented 45 percent of the annual hydrologic input which approximately equaled the evapotranspiration loss of 41 percent. Surface water inflow accounted for 55 percent of total input and 27 percent of output, while net seepage accounted for 31 percent of the outflow from the marsh.

- Dominant plant species with the highest percent cover in the marsh were maidencane, pickerelweed, water-lily and arrowhead. Detailed vegetation analyses and historical aerial photographs documented an increase in nuisance plant species such as primrose willow and cattail which first appeared in areas where the wetland margins had been altered with steeper slopes. Subsequently the nuisance species invaded the marsh itself.

- Soil cores indicate the marsh and sedimentation basins have mineral soils and all concentrations of pesticides, organic priority pollutants, and PCB were below detectable levels. The soils in the west basin contained toxic levels of zinc, probably from roof runoff, and the zinc was increased at the inflow station in the marsh.

- Correlation analysis showed that phosphorous concentrations increased during extended periods between rainfall events. Other relationships indicate that as total suspended solids increase so do iron, lead, copper, and ammonia.

**Project Conclusions:**

- A large wetland to drainage basin ratio should be encouraged. Significant mass pollutant removal occurred in the marsh because only 27 percent of the hydrologic input to the marsh was actually discharged at the outflow. A large wetland to watershed ratio will also protect against detrimental changes in hydroperiod.

- To maintain the existing integrity of the marsh and avoid the adverse impact of invasive plant species, emphasis should be placed on maintaining an undisturbed upland buffer zone around the wetland. Inspections and maintenance should be required to minimize the impact of non-native and invasive plant species in areas within and adjacent to natural
wetlands and invasive species removed.

- Toxic zinc levels in the sediments of the west basin suggests the need for an operation and maintenance guideline for the periodic removal of accumulated pollutants from pretreatment ponds.

- The problem of pollutants in atmospheric deposition needs to be addressed by source reduction.

- The low pH, conductivity and dissolved oxygen typical of many natural wetlands reduces their effectiveness for removing metals and phosphorus.

**District Report Reference:**

An In-Depth Analysis of a Wet Detention Stormwater System and Three Design Alternatives for Stormwater Detention Ponds

Author(s): Betty Rushton, Charlie Miller, Clark Hull and Jeff Cunningham

Year Completed: 1997

Project Cost:
- EPA: $50,000
- District: $170,000

Project Rationale:

Wet detention ponds are the most common method used in our District for treating stormwater runoff, but little data is available about how different designs affect pollution removal. The purpose of this study was to provide scientific documentation to support or modify certain aspects of the District’s stormwater rule (40D-4). Other objectives included measuring pollutant loading from rainfall, correlating relationships between constituents, determining compliance with state water quality goals, measuring pollutants in the sediments and making recommendations for reducing non-point source pollution.

Project Description:

One pond was reshaped three different ways to compare designs that have been used or can be used to meet District surface water runoff rules. Each pond design was studied for an eight month period from June through January of each year. The major features of each design are:

- A shallow pond was studied in 1990. It was originally one foot deep with an average 2-day wet season residence time and 100% vegetated with planted wetland species and the design followed the early parameters established by SWFWMD rules promulgated in 1988.

- The same pond was studied in 1993 except that it had been reshaped with a permanent open water pool five feet deep, which allowed a 5-day wet season residence time. An unplanted shallow shelf (littoral zone) occupied 33% of the pond and was allowed to colonize naturally from the available seed source and the largest part of the shelf was located near the outflow. Design parameters represent SWFWMD criteria in effect in our current rules.

- The pond, reshaped once again, to test the Conservation Wet Detention Design criteria (developed by SWFWMD’s regulatory staff), was studied in 1994. These design criteria include a 14-day wet season residence time and a planted littoral shelf similar in area to the previous pond design. These criteria represent an alternative design that can be used by developers seeking SWFWMD permits.
The drainage basin for the pond is 6.5 acres with about 30 percent of the watershed covered by rooftops and asphalt paving, 6 percent by a crushed limestone storage compound and the remaining 64 percent is a grassed storage area. The impervious surfaces discharge to ditches that provide some pre-treatment before stormwater enters the pond. Instruments at the inflow and outflow collected flow-weighted samples for over 20 storm events during each eight month sampling period. Rainfall amounts and water quality were also quantified. Since treatment credit is given for some of the storage in the permanent pool, the Conservation Wet-Detention design can reduce the amount of fill needed for elevating house pads and also use less land area for the pond.

**Project Results:**

- The most important finding showed the Conservation Wet Detention design that included the 14-day residence time had the best removal efficiency. Also, using these criteria, the reduction of pollutants from the inflow to the outflow usually met the 80 percent pollutant reduction goal specified by the State Water policy.

- Organic nitrogen and ammonia are the most difficult pollutants to remove with wet detention ponds. Ammonia concentrations were reduced by 18% to 70% and organic nitrogen by 5% to 42%. The Conservation wet-detention design had the highest removal rates compared to the other two designs.

- Rainfall is a significant source for nitrogen and some metals.

- Low dissolved oxygen levels (< 2 mg/L near the pond sediments) increase phosphorus concentrations in the water column.

- Sediment samples indicate polycyclic aromatic hydrocarbons (PAH) concentrations present a problem in stormwater runoff and concentrations in sediments increase as ponds age.

- Iron is a controlling mechanism for pollution removal forming positive correlations with metals and phosphorus. Iron was present in higher concentrations at the inflow during the final year of the study and since it forms particles that settle easily it may have improved pollution removal for the final year.

- Macroinvertebrate sampling indicated that newly constructed wet detention ponds can be diverse and productive habitats supporting even some pollution sensitive species.

- Desirable wetland herbaceous species planted on the wide littoral shelf reduced the amount of torpedo grass that had invaded the pond. In contrast, the steep slopes of the narrow littoral shelf around the pond favored the expansion of torpedo grass.

- Much more diverse planted wetland vegetation survived on the wide littoral shelf near
the outflow than on the narrow shelf that surrounded the pond.

**Project Conclusions:**

- The Conservation Wet Detention criteria should be recommended for all stormwater systems where deeper surficial groundwater tables and confining strata allow for adequate pond depth. In this study the effluent, which resulted from using these criteria met almost all State water quality standards and this design can also reduce the need for fill material and produce other economic benefits.

- Stormwater designs that utilize the entire drainage basin and reduce discharge to pre-development levels should be encouraged and credit given to developers who use these techniques. Although stormwater ponds reduce peak flows, only a watershed approach will significantly reduce the volume of water discharged downstream.

- Stormwater rules need to address extreme events. During 1993 in this study, from 32 to 77 percent of all pollutant loads measured during the 22 storms monitored that year were discharged during one storm.

- Source reduction is needed for stormwater improvement since atmospheric deposition was a significant source of inorganic nitrogen and some metals.

- Aerobic bottom sediments and a circumneutral pH in a permanent pool with adequate residence times are a necessary condition for stormwater ponds and designs that provide these conditions should be incorporated into stormwater systems.

- Operation and maintenance information for the care of stormwater systems is needed.

**REFERENCE:**


A Survey of Outflow Water Quality from Detention Ponds in Agriculture

Author(s): Benjamin Bahk and Mark Kehoe  
Year Completed: 1997  
Project Costs: District-$50,000

**Project Rationale:**

Agriculture is considered the major source of non-point source (NPS) pollution to water bodies in the United States. Because of the diffuse nature of NPS pollution, treatment of the discharge waters has been difficult. One method used to treat agricultural runoff is to direct the runoff from stormwater and irrigation to detention ponds. Detention ponds have been used in urban settings to treat stormwater before discharge into environmentally sensitive waters and have proven to act as a filter for pollutants such as metals, nutrients, and other water contaminants. In this study, discharge from detention ponds at nine agricultural sites, which covered a three county area were investigated to assess the outflow water quality and compliance with State water quality standards.

**Project Description:**

From December 1993 through November 1994, monthly water samples were taken from the outflows of nine detention ponds in agricultural basins to assess compliance with State of Florida water quality standards. Three analyses were performed: 1) discharge water quality data were compared with State surface water and ground water standards 2) discharge water quality data were compared with treated and untreated agricultural discharge values found in literature and 3) correlations of water quality data were performed to investigate relationships and trends. For this study, it is important to consider that data was gathered from only the outflow of detention ponds. Water quality data was not gathered at the inflow and therefore, this study does not assess the treatment efficiency nor does it characterize how the detention ponds function. Since the ponds discharged almost continually the samples were collected on a monthly basis and do not necessarily represent storm runoff.

**Project Results:**

- Comparison with State Class III surface water standards indicates that out of nine total sites, violations occurred for lead (2 sites), iron (3 sites), alkalinity (1 site), unionized ammonia (1 site), pH (3 sites), and dissolved oxygen (8 sites).

- Comparisons to ground water were performed to provide additional insight to the water quality because the source of irrigation water which flowed into the ponds was groundwater. Comparison with ground water standards indicates that violations were noted for iron (6 sites), manganese (7 sites), total dissolved solids (7 sites), sulfates (5 sites), and pH (4 sites).
• Although violations of both surface water and groundwater standards were detected, the violations were infrequent. Some of the exceedences were related to the summer rainy season and farming schedules which may have elevated certain water quality parameters.

• Comparisons of agricultural survey data with data from untreated agricultural runoff reported in the literature indicate lower values from the agricultural survey sites in almost all parameters (includes various forms of nitrogen and phosphorous, pH, dissolved oxygen, total suspended solids, and turbidity).

• Comparisons of agricultural survey data with data from treated agricultural discharges reported in the literature, indicate similar water quality values for all parameters (includes various forms of nitrogen and phosphorous, pH, dissolved oxygen, total suspended solids, and turbidity). In some cases, the values from the agricultural survey were actually lower.

• High correlations between hardness, conductivity, total dissolved solids and various ion species such as calcium, magnesium, and sulfate confirmed expected relationships between the variables.

• Unexplained correlations (includes negative correlations) were noted between phosphorous and major ions ($r_s$ value range of -0.77 to -0.61), and also copper and zinc to various major ions ($r_s$ value range of -0.50 to -0.39).

**Project Conclusions:**

• Ponds in this study discharged almost constantly, especially in filtration systems. Designs of detention ponds should be reviewed to maximize treatment ability by increasing retention time and other design criteria.

• In agricultural systems, organochlorine and organophosphorous pesticides are used to control insects and other pests. Pesticides can be introduced into the water column, and have adverse effects on the reproductive and neurological systems of the biological community in the aquatic systems. Pesticides and other anthropogenic compounds should be addressed in characterizing water quality from agricultural sites.

**District Report Reference**

Outfall Water Quality from Wet-Detention Systems

Author(s): David W. Carr and Mark J. Kehoe  
Year Completed: 1997  
Project Costs: District - $60,000

Project Rationale:
This survey study was conducted to statistically compare samples collected before and after discharge over the outfall structure. This was done to validate the feasibility of collecting samples before discharge for compliance monitoring. Additionally, the outfall effluent from permitted wet-detention systems were compared to State water quality standards. This study compared the effluent water quality of two types of permitted stormwater systems: constructed wet-detention ponds and natural wetlands.

Project Description:
A survey of permitted wet detention ponds was conducted between June 1992 and April 1993. Twenty-two systems in the Tampa Bay area were sampled; nine were natural wetlands and thirteen were constructed ponds. Data collection took place during fourteen sampling events. Samples were collected during system discharge from two locations: 1) in the system just before the outflow weir (b side) and 2) after the outflow weir (a side) but before it entered the receiving water. The a side is also referred to as the wet detention system effluent. Water quality sampling included eight metal species, six nutrient species, turbidity, total suspended solids, temperature, dissolved oxygen, pH and conductivity. Study goals were to: 1) compare the water quality in front of the outfall weir to that of its effluent, 2) determine whether the effluent complied with class III Florida State Water Quality Standards and 3) compare the effluent from constructed and natural systems for standard compliance. Additional analyses were conducted to determine relationships between constituents.

Project Results:

- Unionized ammonia, iron, manganese (class III Standard) and nickel measured during this study complied with water quality standards 100 percent of the time. Most constituents complied >79 percent of the time except dissolved oxygen (in noncompliance 64% of the time).

- In a comparison of the metals in noncompliance between the natural and constructed systems, the natural systems had a higher percent noncompliance than the constructed systems (ranging from two to nine times higher). Despite these differences between system types, every metal complied with water quality standards >65 percent of the time.

- A comparison of the data from both sides of the weir in each of the data sets revealed that all constituents measured were not significantly different except dissolved oxygen, turbidity, temperature, and pH. Dissolved oxygen was significantly lower on the b side
of the weir than the \textit{a} side in each of the three data sets caused by aeration as water flowed over the weir. The pH was significantly higher on the \textit{a} side of the weir in the constructed system data set. Turbidity was significantly higher on the \textit{a} side of the weir in the natural system data set. The temperature on the \textit{a} side of the weir in the natural system was significantly higher.

**Project Conclusions:**

- The discharge from constructed systems met State water quality standards more often than discharges from natural wetland systems for copper, lead, zinc, and cadmium. Better compliance with the metal standards observed in the constructed systems may be the result of the generally harder water found in those systems since the standard is hardness dependent. Non-compliance in natural wetlands were: dissolved oxygen (48%), copper (35%), lead (27%). Alkalinity (27%), zinc (18%), and cadmium (9%).

- When water quality from constructed wetlands was compared to State standards, the discharge water failed to meet standards for some of the metals and other constituents. For constructed wetlands, the following were in non-compliance: dissolved oxygen (70%), copper (12%), lead (12%), and zinc (6%).

- No statistical differences were found between the water quality on either side of the weir during discharge (except pH and dissolved oxygen). Thus, samples can be collected from the more accessible \textit{b} side of the weir (just before the water discharged across the weir located inside the pond). Current requirements dictate that samples be taken from the \textit{a} side (after water exits the pond).

- Methods to increase dissolved oxygen in ponds should be considered. Examples include aeration devices (i.e., fountains) and maintenance of a deeper area devoid of vegetation immediately adjacent to outfall weirs.

**District Report Reference:**

An Assessment of an In-line Alum Injection Facility Used to Treat Stormwater Runoff in Pinellas County, Florida

Author(s): David W. Carr  
Year Completed: 1998  
Project Costs: District - $60,000 / SWIM - $249,115 used for construction of the site

Project Rationale:

This study was conducted to determine the feasibility of using an in-line alum injection facility for a stormwater treatment retrofit. Alum treatment is primarily used to remove phosphorus (usually the limiting nutrient in fresh water). Other alum treatment facilities constructed in Florida inject alum into the stormwater flow in storm sewers located upstream of receiving water bodies (e.g., a lake) with the alum floc allowed to settle in the water body. The purpose of this study is to determine the effectiveness of alum technology for an in-line system with limited storage volume for alum floc containment, and to conduct an environmental impact assessment. This study also afforded the District an opportunity to characterize the water quality of an older urban ditched system.

Project Description:

Data collection included flow-weighted storm event samples, monthly water quality samples, and hydrologic data collection. Event based load reductions were calculated, comparisons were made of pre- and post-treatment data, and event and monthly water quality were compared to State surface water quality Class III standards. Additionally, a comparison to event mean concentration (EMC) pollutant reduction was performed between predicted reductions estimated in the permit application and load reductions measured during this study. The water quality constituents analyzed included various forms of phosphorus and nitrogen, and several metals. To some degree, portions of these data were likely biased due to a backflow of alum in the inflow station samples. A detailed analysis of the potential for aluminum toxicity to various fish and benthic species was also conducted.

Project Results:

- Event load reduction calculations were performed on inflow and outflow data collected during seven storm events that were successfully treated with alum. Mean total phosphorus and ortho phosphorus load reductions were 37 and 42 percent respectively. Mean percent load reductions of ammonia and nitrate+nitrite were 24.5 and 52.2 percent respectively while, event total Kjeldahl nitrogen loads increased on average by 5 percent. Zinc loads were reduced in most events (despite the alum solution being contaminated with zinc) and when a single outlier was excluded, mean zinc removal was 41 percent. Iron and lead load reductions were variable with the mean load increasing (export). Dissolved monomeric aluminum event loads were mostly reduced with a mean 56 percent reduction. However, total aluminum mean loads revealed an increase of 258...
percent. This large increase in total aluminum was attributed to inadequate storage volume for the alum floc. Generally, the load reductions outlined above are good considering the settling pond's small size.

- Lead and iron EMCs were in noncompliance less at the outflow than inflow. Copper and zinc EMCs, on the other hand exhibited higher percent noncompliance at the outflow than inflow. The increase in copper and zinc standard noncompliance at the outflow were attributed to these metals being a contaminant in the alum solution.

- Reductions in pH values were mirrored by peaks in aluminum concentrations. This relationship exemplifies the environmental chemistry of aluminum where pH is the driving force in aluminum solubility. Zinc was the sole metal to consistently show concentrations within detectable levels and seemed unaffected by facility operations. Generally, phosphorus concentrations measured downstream of the alum facility were lower and less variable after facility installation. The data suggest that alum residual in the sediment pond tempered phosphorus concentration increases during periods when the injection facility was inoperable. TSS concentration peaks at the outflow were lower after installation. TKN concentrations at all stations showed little change throughout the study due to alum facility installation and operation.

- Inflow and outflow event mean concentration (EMC) data were compared to predicted EMC reductions calculated in the MSSW permit application. Predictions for ammonia and nitrate+nitrite agreed with measured data. Measured changes in pollutant EMCs were a 32 percent increase in total nitrogen, a seven percent decrease in total phosphorus and a 184 percent increase in total suspended solids. EMC predicted percent reduction should not be confused with actual percent load reduction also presented in the report.

**Project Conclusions:**

- The importance of operation and maintenance cannot be over emphasized. The regulatory agencies should require the permittee of an alum injection system to: a) assure sufficient funds are available for repair/replacement of inoperable equipment, b) submit semi-annual operation and inspection reports, and c) require operators to have some level of expertise appropriate for facility operations.

- It is important to maximize alum floc containment volume to minimize potential adverse environmental impacts downstream. The containment volume at this study site was inadequate.

- Despite the operation and maintenance problems experienced, event mean concentration and loads of phosphorus were reduced during alum facility operations. The data indicate the alum facility could be effective in reducing phosphorus if properly maintained.

- Monthly samples showed that phosphorus concentrations measured downstream from the alum injection facility were generally lower and less variable after facility installation.
Potentially toxic concentrations of aluminum to aquatic wildlife were measured at stations immediately upstream and downstream of the alum facility. Aluminum concentrations at stations further downstream were below these potentially harmful levels.

**District Report Reference:**

Removal of Microbial Indicators from Stormwater Using Sand Filtration, Wet Detention, and Alum Treatment Best Management Practices

<table>
<thead>
<tr>
<th>Author(s):</th>
<th>Year Completed:</th>
<th>Project Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond C. Kurz</td>
<td>1998</td>
<td>District $ 45,000</td>
</tr>
</tbody>
</table>

**Project Rationale:**

The Environmental Protection Agency has determined that nearly 90% of fecal coliform pollution to surface waters originated from non-point sources such as urban and agricultural stormwater runoff. In the Tampa Bay watershed, several tributaries, which receive agricultural, industrial, and urban runoff exhibit consistent, elevated total and fecal coliform bacteria concentrations which often exceed State standards for shellfish harvesting and recreational exposure. Based on State water quality standards, 45% of these tributaries did not meet their intended use for recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In urbanized areas, contaminated stormwater can impact recreational beaches in both marine and freshwater environments and can cause a number of bathing-related illnesses including eye, ear, nose, and upper respiratory ailments, skin irritation, and gastrointestinal infections.

**Project Description:**

Very few studies have been conducted to determine how well stormwater management systems reduce microbial indicators from stormwater. In this study, indicators and surrogates of microbial pathogens were used to determine how well three types of stormwater systems reduced microbes using simulated storm events. The indicators used were total and fecal coliform bacteria, MS2 coliphage, and fluorescent beads representing a pathogenic protozoa. The three types of systems were: sand filtration, wet detention and alum coagulation. Samples were taken before the introduction of the surrogate or indicator organisms, right after the introduction and then ten samples at timed intervals were collected to observe die-off effects. Heavy metals, turbidity and total suspended solids were also measured using the same experimental design. Additionally, gram-negative bacteria already in the water were identified during each of the sampling steps.

**Project Results:**

- Significant (p < 0.05) reductions in total and fecal coliform bacteria, MS2, and bead concentrations were observed between inflow and outflow samples for each of the three stormwater treatment systems. On a few occasions, however, greater concentrations of total coliform bacteria, turbidity and total suspended solids were found in outflow samples than at the inflow.

- Using flow-weighted sampling techniques the following reductions were measured at all
three systems. For beads, the reduction was greater than 90% and for MS2 coliphage, greater than 80%. Efficiencies for total and fecal coliform varied widely with total coliform removal values consistently less than 70% while fecal coliform reductions ranged from 65 to 100%.

- Overall, alum coagulation (dose = 10 mg/L) provided the greatest removal efficiencies under controlled laboratory conditions using jar tests.
- Removal efficiencies using sand filtration were generally high for turbidity, MS2, and beads but not for total or fecal coliforms.
- Wet detention using the current regulatory standard of a 5-day bleed-down period provided consistently high removal efficiencies for fecal coliform bacteria, MS2 and beads, and had the greatest TSS removal of the three treatment systems. Water quality standards for total coliform bacteria were exceeded more often during the 14-day trials than the 5-day trials which may have been caused by heavier than normal rainfall.
- A number of gram-negative bacteria were also identified in both the inflow and outflow samples taken from the wet detention ponds including several which are capable of causing human disease. Most of the bacteria were present in both the inflow and outflow samples.
- A small proportion of bacterial removal may have occurred as a result of heavy metal toxicity.

**Project Conclusions:**

- Each of the three stormwater treatment systems evaluated in this study were capable of reducing microbial pollution and each had specific attributes that would make it more advantageous than the other for specific applications or site constraints.
- The use of a multiple treatment system in which several different BMPs are joined in series may offer greater reductions for a broader collection of parameters than any single BMP. Since no single BMP evaluated during this study had consistently greater removals of all the parameters, this approach would be more effective.
- The consistent presence of pathogenic strains of bacteria in both inflow and outflow samples from all of the three sites evaluated further stresses the importance of stormwater treatment to reduce potential public health risks.
- Methods commonly used for wastewater such as chlorine disinfection, ozonation, and uv light irradiation have been suggested for the removal of microbial pathogens from stormwater.
- Since resuspension of sediments can reduce the effectiveness of wet detention ponds,
reducing flow rates at the inflow can be critical to achieving sanitary water at the outflow.

**District Report Reference:**

**BMP Data Transfer Grant**

**Principal Investigator:** Betty Rushton, Ph.D.  
**Year Completed:** 2000  
**Project Cost:** EPA - $9,500

**Project Rationale:**

Money from a BMP data transfer grant paid has made some of our data available on the internet.

The National Stormwater BMP Database was developed by a team of stormwater experts associated with the Urban Water Resources Research Council of the American Society of Civil Engineers under a grant from the U. S. Environmental Protection Agency. Transferability of performance results and consistency, or lack of it, in the performance of various BMPs has been an ongoing problem. The data base process provides a mutually agreed upon minimum list of reporting parameters that can be used to relate the performance of BMPs to some, or all, of these parameters. Over time such standardization will conserve the resources being expended by various field investigations and eventually lead to improvements in the selection of, and the design of various BMPs.

**Project Description:**

The project coordinators requested that data from some of the Districts stormwater research projects be included in this data base, and grant money was provided for data entry. The data base provides access to BMP performance data in a standardized format for at least 98 BMP studies conducted over the past fifteen years. The database may be searched and/or downloaded on the website listed in the reference section. The data fields include site location, watershed characteristics, climatic data, BMP design and layout, monitoring instrumentation, and monitoring data for precipitation, flow and water quality.

**Project Results:**

- Data from four Stormwater research projects conducted by SWFWMD have now been entered into the data base under the grant received from EPA. These include: Three Design Alternatives for Stormwater Detention Ponds, Integrating an Herbaceous Wetland into Stormwater Management, Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Ruskin, Florida, and Florida Aquarium Parking Lot: A Treatment Train Approach for Stormwater Management.

- The master database contains records that have undergone quality assurance review by the National Stormwater BMP database Clearinghouse and contains over 98 BMPs selected from an initial bibliography of over 800 studies.

- The data retrieval process is based on specification of one or more search parameters that may include a combination of state, country, watershed size, BMP type or water quality.
parameter.

- Once the data are retrieved, the user can view, print and/or export the data, revising search criteria as many times as needed. For extensive data analysis a copy of the CD and User's Guide is available.

**Project Conclusions:**

The database is one component of a broader project with the ultimate purposes of identifying factors that affect BMP performance, developing measures for assessing BMP performance and using the findings to implement design improvements.

**Reference:**

www.Bmpdatabase.org
Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Cockroach Bay, Florida (Phase I)

Author(s): Betty Rushton, Ph.D.  
Year Completed: 2001  
Project Costs: EPA - $155,407 / District - $103,604

Project Rationale:
Agriculture has been identified as a significant source of water pollution in the United States. The use of agricultural fertilizers and pesticides doubled from the mid 1960s to the early 1980s and may be responsible for a major portion of surface and ground water contamination. The effects of agricultural pollution are numerous and include: sediment contamination and deposition with subsequent impairment of aquatic habitat, pesticide contamination, eutrophication of surface waters, and general water quality degradation of downstream water bodies. The Environmental Protection Agency (EPA) ranks agricultural activity as the greatest threat to water quality in streams and lakes. The EPA also notes that nutrient and silt runoff are the leading causes of water quality impairment. Given the water quality problems associated with agriculture, the Southwest Florida Water Management District initiated a study on the effectiveness of a wet-detention pond to treat stormwater runoff from an agricultural basin.

Project Description:
The Cockroach Bay Restoration Project in Ruskin, Florida is an effort to reclaim over 650 acres of natural habitat in a landscape historically used for row crop agriculture. As a part of the larger reclamation landscape, two wet-detention ponds in series receive stormwater runoff from 210 acres of active row crop farmland. The monitoring of the Cockroach Bay Stormwater Project included flow-weighted sampling of inflow and outflow to the detention ponds, as well as collection of rainwater for chemical analysis. The main goal of this project is to assess the treatment efficiency of the wet-detention ponds. The primary constituents monitored include nutrients, metals, ions, pesticides, and bacteria. Additionally, continual measurements of pond water level, temperature, pH, dissolved oxygen and conductivity are recorded in data loggers. Other monitoring efforts include bi-weekly measurements of depth to groundwater around the ponds, quarterly ambient grab samples in the pre-treatment ditch, water quality in groundwater wells and yearly samples of the sediments.

Project Results:
- A complete water budget estimated for storm events showed most (>70%) of the water enters and leaves the pond at the two control structures. In addition, about 25 percent of all the storm input to the ponds is introduced by rainfall directly on the pond. Additional water export from the pond for the duration of storm events was estimated at 8 percent by evapo-transpiration; and 15 percent by net seepage.
- The large pervious area in the drainage basin as well as the pre-treatment ditch and sandy
soils contributed to low runoff coefficients. During the rainy season when ample moisture was available the estimated runoff coefficient showed that 10 to 30 percent of rainfall was discharged from the drainage basin into the pond. During dry periods only 1 to 10 percent of rainfall ran off.

- In general, inorganic nitrogen (ammonia and nitrate) have their highest concentrations in rainfall, but even with this atmospheric input, nitrate had the greatest percent reduction of all constituents measured (greater than 90% in 1999 and 2000). In contrast, organic nitrogen often increases between the inflow and outflow, probably as a result of nitrogen transformations taking place.

- Phosphorus is measured at relatively high levels at the inflow to the pond with average concentrations of total phosphorus near 1 mg/L. Although average concentrations at the outflow for phosphorus are reduced by about 40 percent, the concentrations still exceed by a factor of 5 to 8 the suggested EPA goal for streams and rivers of 0.1 mg/L.

- During the three years of study (70 rain events), over 65 percent of all the pollutant loads for potentially toxic metals entered the pond during five El Nino storms. Larger loads are more easily reduced in wet-detention ponds and the goal of 80 percent reduction is met for most metals in 1998 and 2000 and nearly so for inorganic nitrogen. Percent reduction was poorer in 1999, a drought year.

- Ten pesticides or degradation compounds (chlordane, chlorothalonil, DDE-p,p', endosulfan, endosulfan II, diazinon, malathion, metalazyl, metribuzin and endosulfan sulfate) were detected in stormwater runoff at the inflow of the detention pond. At the outflow, only four pesticide degradation compound, the endosulfan series, were detected. Based on the number of pesticides detected at the inflow vs. outflow, the detention pond seems to function as a sink for pesticides.

- Chlorophyll was measured monthly at the inflow and outflow of the pond and except during periods of stagnant conditions the ponds reduced all species of Chlorophyll by a significant amount (Chlor a at the inflow 37.6 ug/L and at the outflow 8.25 ug/L).

- Sediment samples for metals and phosphorus increased dramatically from 1997 to 1998. Phosphorus concentrations were highest in the most overgrown part of the pre-treatment ditch and in the center of the two ponds. The highest concentrations of metals occurred in the marsh after water leaves the pond. These elevated levels can by explained by esturine mixing at the fresh water/salt water interface.

- Ground water levels were measured in 12 shallow wells surrounding the pond and show a close interaction with pond levels. The water table gradient is toward the pond and eventually the outflow marsh. When pond levels are high the gradient is out of the pond and when pond levels are low the surrounding water table to the north seeps into the pond.

**Project Conclusions:**
• The wet-detention pond was effective for reducing most pollutant loads by at least 60 percent, and often, over 80 percent especially in 1998 and 2000 which had higher concentrations of pollutants entering the pond.

• The differences in efficiency of the pond to reduce pollutants during different years demonstrates the need for more long term studies, especially those that investigate processes going on in the pond.

• Maintenance guidelines need to be developed for wet-detention ponds especially since maintaining ponds may help reduce total suspended solids and organic nitrogen which sometimes increased from the inflow to the outflow in these ponds.

• More data are needed to determine treatment efficiency as ponds age. This study suggests that recently constructed ponds are much better at some forms of pollution removal.

**District Report Reference:**

Florida Aquarium Parking Lot: A Treatment Train Approach for Stormwater Management

**Author(s):** Betty Rushton, Ph.D.  Rebecca Hastings

**Year Completed:** 2001

**Project Costs:** EPA - $196,996 / District - $131,331

**Project Rationale:**

Impervious surfaces such as parking lots and roof tops cause more stormwater runoff and pollutant loads than any other type of land use. Low Impact Development (LID) design criteria provide alternatives that have successfully reduced runoff and pollution loads by reducing imperviousness, conserving ecosystems, maintaining natural drainage courses, reducing the use of pipes and minimizing clearing and grading. Providing rainfall runoff storage throughout the entire drainage basin disperses runoff uniformly throughout a site’s landscape by using a variety of detention, retention, and other practices. A parking lot at the Florida Aquarium in Tampa is being used as a research site and demonstration project to quantify how small alterations to parking lot designs can dramatically decrease runoff and pollutant loads.

**Project Description:**

An innovative parking lot design using LID techniques has been implemented for the Florida Aquarium and utilizes the entire drainage basin for stormwater treatment. The study site is an 11.5 ac parking lot serving 700,000 visitors annually. Automatic instruments collect flow-weighted water quality sample and measure flow and rainfall during storm events. The research is designed to determine pollutant load reductions measured from three elements in the treatment train: different pavement types in the parking lot, a planted strand with native wetland trees and a small wet-detention pond used for final treatment. (In this study swales are small depressions between parking rows and strands are larger swales). The parking lot research involved testing three paving surfaces as well as testing basins with and without swales. This makes four treatment types with two replicates of each type. The paving surfaces are asphalt, concrete and porous paving. A total of 59 rain events are included in the data set and represent storms that produced as little as 0.37 inches of rain to a maximum amount of 2.91 inches. The monitoring effort also investigated other processes taking place by measuring rainfall, sediments, as well as variations in pH, dissolved oxygen, temperature, turbidity, and weather conditions.

**Project Preliminary Results:**

- The runoff coefficient is a ratio that can be converted to a percentage and for traditional parking lots a typical range is 70 to 90 percent of rain falling on the site would run off. At the Florida Aquarium site even the basins with only small garden areas and no swales measured the yearly average runoff at about 55 percent. The basins with swales and paved in asphalt or concrete reduced runoff to 30 percent and porous paving, to about 16 percent. The basins with larger garden areas reduced runoff by an additional 50 percent.
When the volume of water discharged from all the different elements in the treatment train (the swales, the strand and the pond) are compared, calculations showed almost all the runoff was retained on site. Although the year sampled was during an extreme drought, it is estimated that even during a normal year, discharge would have taken place only about four or five times and the amount would have been greatly reduced.

For larger storms, permeable paving did not reduce runoff much more than the other basins with swales.

Phosphorus concentrations are highest in the basins with vegetated swales and phosphorus loads were actually increased in basins with swales, although porous paving and larger garden areas ameliorated this effect somewhat.

Most metals (iron, lead, zinc, manganese, copper) have higher concentrations in basins paved with asphalt.

Nitrate and ammonia most often enter the system directly in rainfall with a correlation coefficient of 0.84 for nitrates and 0.48 for ammonia measured at the basins with no swale. Nitrate-nitrogen and total nitrogen appear to be measured in fairly similar concentrations in all basins while ammonia concentrations are variable. Regression equations show increased concentrations of nitrate in rainfall result in increased concentrations in runoff for all basins.

Sediment samples indicate that metal pollutants are not contaminating the water table and that most metals are sequestered in the surface soils.

**Project Conclusions:**

- The whole basin approach for the parking lot was an excellent design alternative with no discharge off site. By flexibly interpreting stormwater regulations and taking two feet from the end of each parking space, land was provided for the swales without reducing the number of spaces. This design also did not compromise parking since the front end of the car extends over the swale rather than impermeable paving. Other sensible innovative strategies need to be implemented where land is at a premium.

- Permeable paving reduces runoff from small rain events, but swales are more effective for reducing runoff from all events.

**District Report Reference:**

Rushton, Betty T. and Rebecca Hastings. 2001. Florida Aquarium Parking Lot: A Treatment Train Approach For Stormwater Management, Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609
The Hydrologic Effect of a Large Constructed Wet Detention Pond Located Adjacent to Wetland(s)

Author(s): David W. Carr  
Year Completed: 2002  
Project Costs: District - $17,398

Project Rationale:

Developers often excavate large ponds, use the spoil as fill on-site, and utilize the ponds as wet detention systems. These ponds are commonly built adjacent to wetlands which can adversely affect wetland hydrology. This study was designed to answer several questions posed by District regulatory staff: 1) will a pond built in the above manner, located next to a wetland, alter the wetland's hydrology and impact its functions? 2) how does such a pond affect the wetland's hydrology? 3) if adverse impacts occur, what can be done to avoid these impacts? A site in southern Pasco county was chosen for the project. The site was selected from an in-house conceptual permit to allow for a minimum of one year pre-construction data collection. Hydrologic conditions will be monitored continuously before, during, and after pond construction.

Project Description:

The monitoring and data collection process include: wetland delineation (conducted or verified by SWFWMD regulatory staff), evaluation/characterization of wetland baseline conditions by rating the wetland(s) using the wetland assessment methodology developed by the Environmental section, and conducting vegetation analyses each May/June and August/September. This assessment consists of appropriate transects and quadrats to monitor changes to vegetation. Rainfall, surface water level and surficial groundwater level are continuously monitored. Piezometers are monitored biweekly and quarterly surface water quality sampling (TSS, nutrients, metals, pH, D.O., etc.) is performed quarterly.

Project Results:

Project on-going

Conclusions:

Project on-going

District Report Reference:

Project on-going
Treatment of Stormwater Runoff from an Agricultural Basin by a Wet-Detention Pond in Cockroach Bay, Florida (Phase 2)

Author(s): Betty Rushton, Ph.D.  Rebecca Hastings
Year Completed: 2002
Project Cost: EPA $77,455 / District $51,647

Project Rationale:

The project will provide data for an additional year to enhance the information collected from an existing three year project (see Cockroach Bay phase I). The wet detention pond is part of a watershed project designed to control non-point source pollution to a priority water body that has an impaired or protected use. Tampa Bay has been designated as the number one priority water body in the Southwest Florida region by SWIM. Field investigation involving treatment for agricultural runoff from row crops is limited. This project will provide insight into methods to support district (WMD), state (DEP) and federal (EPA) stormwater runoff guidelines and will add to the statewide stormwater data base documenting the efficiency of wet detention ponds.

Project Description:

The study provides an additional year of hydrology and stormwater data covering all seasons. The data will be used to calculate loading rates and will more thoroughly document the efficiency of the wet detention pond in reducing agricultural pollutants. Samples from a network of wells will indicate possible groundwater pollution from agricultural practices and an adjacent wastewater package treatment plant. Sediment samples in the pre-treatment ditch, the pond and the receiving marsh will indicate pollutant build-up and indicate maintenance requirements.

Project Results:

On-going

Project Conclusions:

Project on-going

Stormwater Management Alternatives Demonstration Project
**Project Rationale:**

Better maintenance procedures and retrofits designed to improve the discharge water quality from stormwater systems are necessary if these systems are to meet State water quality goals. A demonstration project to educate the public about stormwater systems and provide professionals with innovative ideas that can be used for stormwater management will result from the project. Additionally, a monitoring program will measure pollutant loads discharged to the bay from an effluent filtration system and a modified wet detention pond. Also the water quality and flow discharged through the underground filter system on a daily basis will be quantified. A literature summary will provide concise information about stormwater management alternatives. The site is part of a low impact parking lot design, which has already demonstrated its ability to reduce runoff and pollution.

**Project Description:**

During the first year of the study background data has been collected from the existing ponds. During the second year, pond improvements and maintenance alternatives will be implemented and the ponds monitored to quantify the results. The exact methods will depend on the results of the literature review but might include bubblers, pre-treatment devices, vegetation changes or minor pond alterations such as excavating a deeper permanent pool. Sediment samples and an invertebrate study have provided additional information.

**Project Preliminary Results:**

- Chemical treatment of floating algae with copper is usually unsuccessful and often results in discharges of toxic levels of copper and higher levels of nitrate as the algae die.
- Phosphorus is released from the sediments into ponds at low dissolved oxygen levels (below 2-3 mg/L).
- The under drains in the effluent filtration system discharged constantly and indicate that on a yearly basis this runoff was a greater amount than discharged over the weir during storm events.
- Nitrates, ammonia and phosphorus were measured at the highest levels in the under drain pipes of the effluent filtration system.
- Metals and to a lesser extent phosphorus increase when total suspended solids increase.
- Phosphorus concentrations were highest in the pond with the highest concentrations of phosphorus in the sediments, especially when dissolved oxygen levels were low.
The three ponds surveyed showed wide variations in the number of invertebrates collected. The well-oxygenated pond with no chemicals added had the greatest diversity, the anaerobic pond with only a thin layer of sediments over a cement bottom had about half as many invertebrates, and the pond treated once a month with algicide had only one invertebrate species. Fluctuating salinity levels may have also influenced these results.

**Preliminary Project Conclusions:**

- Ponds with nuisance plant problems need remedial solutions other than chemical treatment with copper. Some suggestions for improving the pond after cleaning out the muck include: a) maintaining a deep water permanent pool, b) planting submerged macrophytes which pump oxygen into the water, c) installing a bubbler or fountain, d) using a pre-treatment device such as a bioretention garden or sediment sump.

- Appropriate fish and other aquatic species stocked in the ponds might improve the ecological balance, provide a way to estimate pond health, and help control nuisance species such as mosquitoes.

- Effluent filtration systems should not be permitted except under exceptional conditions. They are usually not properly maintained and export higher levels of dissolved nutrients than other stormwater systems.

**District Report Reference:**

Rushton, Betty T. 1998. Sources and Sinks for Stormwater Pollutants. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609

2002. Report in progress. Southwest Florida Water Management District, 2379 Broad Street, Brooksville, Florida 34609
Broadway Outfall Stormwater Retrofit Monitoring Project (Phase 2)

**Author(s):** Betty Rushton, Ph.D.  Rebecca Hastings

**Year Completed:** 2004  
**Project Cost:** EPA $162,550 / District $108,374

**Project Rationale:**

The Broadway Outfall drainage basin is approximately 132.4 acres in size and includes a 30.6 acre high intensity commercial district. The entire commercial district, which is 100% impervious, was constructed prior to the implementation of the state's stormwater discharge rule. All rainfall incident on these 30.6 acres discharges directly into the Hillsborough River reservoir untreated, resulting in virtually all the contaminants accumulated between inter-event dry periods being conveyed directly to the river. In addition to the commercial district, the Broadway Outfall drainage basin includes residential, multi-family, institutional, recreational land uses including a golf course. The retrofit project has installed a Model PSW70XX (26 cfd capacity) CDS unit in series with an excavated sediment sump immediately downstream, followed by a shallow linear marsh system extending approximately 500 feet downstream. Phase 2 of the project will collect two years of data, including most storm events, to determine the efficiency of the system to remove pollutants.

**Project Description:**

The monitoring of the Broadway Outfall project includes collecting flow weighted samples before stormwater enters the CDS unit, again after it leaves the system and finally as it leaves the marsh system. Rain water will also be collected for chemical analysis. Flow will be measured before stormwater enters the system and at the outfall structure. It is assumed that the same amount of water will leave the CDS unit as enters the sealed tank. The amount of flow that bypasses the CDS unit will also be estimated. Base flow will be collected on a consistent schedule. In addition, wells surrounding the site will analyze water table interactions, sediment samples will determine pollutants retained on site and macroinvertebrate sampling will also be conducted. The major goal of the project is to assess the efficiency (pollutant removal) of the various treatment elements. The primary constituents monitored include nutrients, metals, ions, pesticides, and priority pollutants.

**Project Results:**

Since the monitoring project will not begin until March 2002 there are no results. However, some pre-construction sediment and water quality grab samples have been collected and they indicate some of the potential problems.

- The concentrations of semi-volatile organic pollutants in the sediments where stormwater was first discharged from the pipe into the ditch were high and some exceeded toxic standards. For example, concentrations (ug/kg) were: Fluoranthene 41,000, Benzo(a)anthracene 24,000, Chrysene 26,000, pyrene 35, 000. These were reduced to
undetectable levels in the middle section of the ditch and increased, but at lower levels, as the ditch receives runoff from more commercial development.

- Five PAHs were also detected in the water column at the inflow of the ditch, but not after water traveled further down the water course.

- No pesticides were detected in the sediments, but atrazine and hexazinone were measured in the water column.

- Anoxic conditions (low dissolved oxygen) were measured in the ditch.

**Project Conclusions:**

Project on-going
CONCLUSIONS

Research at the District over the past fourteen years indicate permitted stormwater systems greatly reduce pollutant load to our rivers, lakes and estuaries. But some changes to the rules could improve stormwater quality and quantity problems. These changes do not necessarily represent a new mandate or regulation, but instead should provide strong economic and market incentives that benefit the public, local governments, developers, and the environment. Strengthening and enforcing the rules that already exist are other alternatives to meet the recommendations. Of some concern is the fact that discharge waters from permitted systems still exceed water quality standards for dissolved oxygen and metals. For example, overall average exceedences of State standards for constructed wet-detention are: 12% for copper and lead, and 6% for zinc. Another concern is that as population increases and more impervious areas are created even low concentrations of pollutants will continue to increase loads because the volume of runoff will increase. Also, little studied aspects of stormwater pollution such as bacteria and priority pollutants may present potential threats to people and the environment and warrant further investigation. In addition, the removal rate for total nitrogen is highly variable and sometimes even increases from the inflow to the outflow of ponds. The current rules still allow 20% of suspended solids to discharge to the receiving water.

- Basin wide stormwater treatment, where every opportunity in the drainage basin is utilized for infiltrating runoff, will reduce storm volumes and pollutant loads. Low impact designs should be encouraged and developers should be given stormwater credit when they use these techniques. Designs should be based on percent pervious area and guidelines adopted for stormwater reuse, permeable paving, roadside swales, or other methods used to offset increased impervious area. Other solutions include using the Conservation wet detention design, which can reduce pond size and require less fill for raising the level of houses.

- Almost all studies identified atmospheric deposition as a major source of nitrogen and some metals. The District should work with other agencies to try to clean up this input of pollution at the source.

- Wetlands can be used as part of a stormwater system but stormwater should be treated by conventional methods before discharge to the wetland. Stormwater will change the physical and chemical properties of oligotrophic isolated wetlands that normally receive most of their input from rainfall. A buffer area large enough to discourage the invasion of nuisance species should be left around the wetland.

- Careful consideration should be made before intermittently flooded stormwater systems are selected for stormwater treatment. Necessary conditions should include coarse-grained sandy soils, the bottom of the pond at least three feet above the seasonal high water table and an adequate maintenance plan.

- Effluent filtration systems should not be an option for stormwater treatment unless the systems can meet stringent requirements. These systems, which cease to function
properly when filters clog, create intermittently flooded conditions that cause mosquito problems. The discharge water from the under drains also have some of the highest levels of nitrogen and phosphorus.

- Although stormwater treatment systems reduce pathogenic strains of bacteria, bacteria were still present at the inflow and outflow of all three of the stormwater systems studied. More effective treatment of pathogenic strains of bacteria need to be investigated.

- Operation and maintenance guidelines for stormwater systems are an urgent need. Chemical treatment of floating algae is usually unsuccessful and often results in discharges of toxic levels of copper and higher concentrations of nitrate. Often as a result of poor maintenance, ponds with low dissolved oxygen levels release phosphorus and some metals from the sediments. Conditions conducive to an oxygenated water-sediment interface should be part of the pond design and maintenance plan. These conditions include an open water permanent pool, good wind fetch and good mixing by maximizing the distance between the inflow and outflow.

- Low Impact Development (LID) designs need to be incorporated into the landscape especially in parking lots and for big box stores. Greater reliance on runoff interception and treatment at several points in a drainage basin should be encouraged in designing stormwater facilities.
GLOSSARY

**Aerobic** - Refers to situations where oxygen is relatively abundant and organisms dependent on its availability can survive.

**Alum** - Aluminum sulfate is a clear, odorless, light green or amber liquid used for water quality treatment.

**Alum Coagulation** - A small floc produced when alum mixes with stormwater which attracts suspended and dissolved pollutants. The pollutants become bound to the floc, which settles and becomes incorporated into the sediment.

**Alum Injection** - Consists of flow meters, which measure stormwater flowing in the storm sewers, and injectors which periodically add a predetermined dose of alum to the stormwater as it moves through the storm sewer.

**Anthropogenic Compounds** - Compounds originating from human activity.

**Ambient** - Surrounding.

**Ammonia** - Inorganic nitrogen species (NH$_3$) essential as a nutrient.

**Aquatic** - Pertaining to flooded environments. Over a hydrologic gradient, the aquatic environment is the area waterward from emergent wetlands and is characterized by the growth of floating or submerged plant species.

**Aquatic Plants** - Plants indigenous to aquatic environments

**Atmospheric Deposition** - Refers to the introduction of substances from the air. Can include both wet (rain, snow) and dry (dust) deposition.

**Best Management Practices (BMPs)** - Refers to the practices used for a given set of conditions (e.g., soil type, water shed area, and land-use) that will achieve a satisfactory water quality and water quantity at a minimum cost.

**Biogeochemical Cycles** - Constituent cycling through various chemical, physical, and biological transformation processes.

**BMP** - Best Management Practices (see above definition).

**Buffer Zone (for wetlands)** - An area adjacent to a wetlands which protects wetland function and minimizes adverse impacts of upland development on wetland function.

**Continuous Deflective Separation Technology (CDS)** - Uses fluid flows and a perforated screen to cause a natural separation of solids from fluids. Installed underground in the flow path, the pollutants are deflected away while the water passes through a fine separation screen.
**Conservation Wet Detention Design** - Design criteria developed by SWFWMD's Technical Services staff which can be used as an alternative design for wet-detention ponds to treat stormwater runoff. It includes a 14-day residence time, credit for stormwater storage in the permanent pool, and other criteria that may make it possible to use less land area for the pond and reduce the amount of fill necessary for raising building pads. The entire procedure is available from SWFWMD's Regulatory department or in the publication "Three Design Alternatives for Stormwater Detention Ponds" summarized in this report.

**Constructed Wetland** - A wetland that is purposely constructed by humans in a non-wetland area.

**Correlation Analysis** - Measurement of the intensity of association observed between any pair of variables and to test whether it is greater than could be expected by chance alone.

**Disease Vector Species** - An organism such as a mosquito that carries pathogens from one host to another.

**Dissolved Oxygen** - The concentration of oxygen held in solution in water.

**Drainage Basin** - A subdivision of a watershed.

**Dry Effluent Filtration** - See Filtration

**Effluents** - A liquid or gas that flows out of a process or treatment system. Effluent can be synonymous with wastewater after any level of treatment.

**Effluent Filtration** - See Filtration

**Evapotranspiration (ET)** - The combined processes of evaporation from the water or soil surface and transpiration of water by plants.

**Event Mean Concentration (EMC)** - The amount of a single pollutant concentration measured on a flow-weighted basis and composited together for a single storm event, i.e. more sample aliquots are collected proportionally when flow is high and fewer samples are collected when flow is low. EMC’s represent the entire storm in concentration per volume of sample and are usually reported as mg/L or ug/L.

**Eutrophication** - The processes that results from high concentration of dissolved nutrients in a water body.

**Fecal Coliform** - Aerobic and facultative, Gram-negative, non-spore forming, rod-shaped bacteria capable of growth at 44°C (112°F) and associated with fecal matter of warm-blooded animals.

**Federal National Pollutant Discharge Elimination System (NPDES)** - Federal legislation
aimed at regulating pollutant discharges to surface waters.

**Filtration** - A family of practices in which the runoff from a rain event is allowed to percolate into the soil rather that discharge off-site. Infiltration practices include basins, trenches, dry wells, pervious pavement, and to a certain extent, swales. **Effluent filtration** or exfiltration is the water that percolates out of the system. The amount of infiltration depends on permeable soils and a seasonal high water table or bedrock at least three feet beneath the bottom of the pond. Wet filtration systems have a permanent wet pool and **dry filtration** ponds dry out completely within three days after a storm event.

**Flow-Weighted Sample** - Stormwater samples collected proportionately to the amount of flow generated by a storm.

**Grab Sample** - Water sample collected at a specific time during the hydrograph, not based on flow.

**Groundwater Recharge** - The replenishment of the groundwater from infiltration of water from the ground surface.

**Herbaceous Wetland** - A wetland characterized by herbaceous (non-woody) vegetation.

**Hydroperiod** - The period of wetland soil saturation or flooding. Hydroperiod is often expressed as a number of days or a percentage of time flooded during an annual period, i.e.- 25 days or 7 percent.

**Inorganic Nitrogen** - Non-organic nitrogen often necessary as an essential nutrient.

**Intermittently Flooded (IF)** - Not flooded continuously.

**Impervious Area** - Land surfaces which do not allow, or minimally allow, the penetration of water; examples are buildings, non-porous concrete and asphalt pavements, and some fine grained soils such as clays.

**Isolated Wetlands** - Any wetland without a direct hydrologic connection to a lake, stream, estuary or marine waters.

**Littoral Zone** - The shoreward zone of a lake or wetland. The area where water is shallow enough to allow the growth of emergent vegetation.

**Load Reductions** - See Pollutant Reduction.

**Loads** - See Pollutant Loads.

**Macroinvertebrate** - Invertebrates (organisms without backbones) visible to the eye unaided by a microscope.
Macrophytes - Macroscopic (visible to the unassisted eye) vascular plants.

Major Ion Concentrations - Concentrations of ions of such elements as calcium, magnesium, sodium, potassium, etc. found in water.

Mean - Average

Microbial Pathogens - Bacteria, viruses, or protozoans which can cause disease.

Monomeric Aluminum - A reactive and toxic form of aluminum represented by the chemical notations of Al$^{3+}$ and Al(OH)$_2$$^+$.

MSSW Rule - Legislation relating to Management and Storage of Surface Waters.

Natural Wetland - A wetland ecosystem that occurs without the aid of humans.

Non-point Source Pollution (NPS) - Refers to diffuse pollution that results from many unspecified sources of emission or discharge to the atmosphere or waterways (e.g., auto emissions).

Nuisance Plant Species - Vegetation which dominates areas and does not allow for establishment of other species.

Oligotrophic - Water quality characterized by a deficiency of nutrients.

Organic Nitrogen - Nitrogen that is bound in organic compounds.

Organic Priority Pollutants - Organics such as pesticides, petroleum based hydrocarbons, and other complex organic compounds. The source list for organic pollutants is long ranging from common household items, to industrially produced by-products. Recent medical advances show correlations between these organics and potential harm to human health.

Organochlorine Pesticides - Compounds in which chlorine is bound to a hydrocarbon group. Used as a pesticide.

Organophosphorous Pesticides - Compounds in which phosphorous is bound to a hydrocarbon group. Used as a pesticide.

ORP - Oxidation Reduction Potential.

Oxidation Reduction Potential (ORP) - (or Redox potential expressed as Eₐ or Eₗ), refers to the standardized measurement of the potential for electron loss (oxidation) or for electron gain (reduction) under present systems (Fe$^{2+}$ to Fe$^{3+}$), although the oxidized and reduced states exist together in equilibrium. Removing free electrons causes further oxidation, while adding
electrons inhibits oxidation and promotes reduction (Fe$^{3+}$ to Fe$^{2+}$). ORP is proportional to the equivalent free energy change per mole of electrons associated with a given reduction.

**Peak Flows** - The highest point of a hydrograph during which maximum flow occurs.

**Permanent Open Water Pool** - A permanent water pool in stormwater BMPs such as a detention pond. It is the water stored below the outflow discharge elevation.

**Permeable Pavement** - Pavement which allows for the infiltration of water.

**Pervious Area** - An area that allows for the infiltration and percolation of water through the ground.

**Phosphorus** - An essential nutrient to vegetation.

**Photosynthesis** - The biological synthesis of organic matter from inorganic matter in the presence of sunlight and chlorophyll.

**Pollutant Loads** - Calculated from event mean concentrations (EMC) and storm volume over a representative time period.

\[
\text{Pollutant Loads} = 3 \ EMC \times \text{storm volume}
\]

Where EMC is the event mean concentration for the storm and storm volume is the amount of runoff measured flowing into or out of the system. The mass loading rates can be expressed as kilogram per square kilometer per year or pounds per acre per year.

**Pollutant Reduction (efficiency)** - Analysis of Event Mean Concentrations and pollutant loads provide the basis for calculating the pollutant removal capability of the stormwater system. This is often referred to as the efficiency of the system to remove pollutants.

Concentration efficiency:

\[
\text{EMC efficiency} (\%) = \frac{(\text{concentrations in} - \text{concentrations out})}{(\text{concentrations in})} \times 100
\]

Where: Concentrations is the event mean concentration (EMC) for each storm event

Load efficiency:

\[
\text{Load efficiency} (\%) = \frac{(\text{SOL in} - \text{SOL out})}{(\text{SOL in})} \times 100
\]

where: SOL is the sum of loads in cubic feet or cubic meters for a representative time period.

**Polychlorinated Biphenyls (PCBs)** - PCB's were used in a number of throw-away applications and also extensively employed as an electrical insulating fluid. Environmental concerns have lead to strict controls on the use of PCB's and standards for cleanup of PCB discharges.
**Polycyclic Aromatic Hydrocarbons (PAHs)** - Priority pollutants of concern containing benzene rings which tend to be biodegradable and adsorbable on solids.

**Potable Water** - Drinking water. Water whose chemical constituents do not exceed the limits set fourth in the State Safe Drinking Water Act.

**REV (Rate-Efficiency-Volume)** - REV stands for reuse rate, efficiency of reduced discharge, and volume of temporary storage. Variables used in descriptive charts (i.e.- measuring aspects of a reuse pond).

**Reclamation** - The practice of converting land use back to a natural state.

**Redox** - Refers to the oxidation-reduction potential.

**Removal Efficiency** - The difference between the mass/volume input and mass/volume discharge for a pollutant; or the change in concentration from the input to the output, usually on a flow weighted (total mass/total volume) basis over the duration of a storm event.

**Residence Time** - The average amount of time water stays in detention before being discharged.

**Restoration** - The return of an ecosystem from a disturbed or altered condition to a previously existing natural condition as a result of human action, i.e.- fill removal.

**Retention Ponds** - The prevention of direct discharge of storm runoff into receiving waters; included as examples are systems which discharge through percolation, exfiltration, and evaporation processes and which generally have residence times less than 3 days (see filtration).

**Retrofits** - The reconstruction of existing stormwater facilities to improve or comply with current needs and standards.

**Reuse** - The application of reclaimed water for a beneficial purpose.

**Sand Filtration System** - The filtration of stormwater through sand for water quality treatment.

**Secondary Sewage Treatment** - After removal of solids in primary treatment, secondary treatment attempts to reduce nutrients (N and P) and organic material using bacteria and other microbes in activated sludge or trickle filter systems.

**Sedimentation Basins** - Settling basins that are usually incorporated as pre-treatment basins in stormwater systems to help reduce sediment deposits in receiving waters or in constructed or natural wetlands used in stormwater treatment.

**Seepage** - Areas of discharge of groundwater to the ground surface.

**Soil Cores** - Samples of the vertical profile of sediment or soil layers.
**State Water Policy** - The comprehensive statewide policy as adopted by DEP pursuant to 373.026 and 403.061 setting forth goals, objectives, and guidance for the development and review of programs, rules, and plans relating to water resources. All Water Management District's programs and rules must be consistent with State Water Policy.

**State Water Quality Standards** - Water quality criteria set by the State of Florida for its surface waters (Chapter 62-302 F.A.C.).

**Stormwater** - The flow of water that results from, and that occurs immediately following rainfall events.

**Stormwater Utilities** - Utility which relies on user fees rather that the government's limited general tax revenues.

**Stratification** - The formation of a boundary layer in lakes from differences in water temperature or density.

**Street Drain Trash Basket** - Baskets placed in street stormwater drains used to catch trash in runoff.

**Swales** - A gently sloping depression in the land surface designed to transport intermittent runoff from storm events.

**Total Kjeldahl Nitrogen** - A measure of reduced nitrogen equal to the sum of Organic Nitrogen and Ammonia Nitrogen.

**Total Maximum Daily Load (TMDL)** - The greatest amount of a pollutant that a water body can receive without violating water quality standards.

**Total Suspended Solids (TSS)** - A measure of the filterable matter in a water sample.

**Treatment Train** - The use of multiple stormwater best management practices to provide a series of water quality treatments.

**Upland** - Any area that is not an aquatic, wetland, or riparian habitat. An area that does not have the hydrologic regime necessary to support hydrophytic vegetation.

**Urban Runoff** - Stormwater runoff generated in urban areas typically characterized by high impervious areas.

**Volatile Solids** - The weight loss on ignition (550°C) of the dissolved solids fraction for the solids laboratory analysis is called "volatile solids". Although the test does not distinguish precisely between inorganic and organic matter since it also includes some mineral salts, it is sometimes used for this purpose.
**Watershed Management** - The integration of land use, infrastructure and water resources throughout an entire watershed.

**Water Table** - The upper surface of the groundwater or saturated soil.

**Weir** - A device used to control and measure water or wastewater flow.

**Wet-detention Pond** - A water quality treatment system that utilizes a design water pool in association with water-tolerant vegetation to remove pollutants through settling, adsorption by soils and nutrient uptake by the vegetation. The bottom elevation of the pond must be at least one foot below the control elevation.

**Wetland** - An area that is inundated or saturated by surface or groundwater at a frequency, duration, and depth sufficient to support a predominance of emergent plant species adapted to growth in saturated soil conditions.