A REVIEW OF URBAN STORMWATER RETROFITTING IN FLORIDA

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ABSTRACT

With the implementation of the State Stormwater Rule in February 1982, stormwater discharges serving new development or redevelopment were required to be treated by the incorporation of site appropriate best management practices (BMPs) into the project's stormwater management system. The implementation of this program has greatly reduced the impact of stormwater discharges on aquatic resources, especially given Florida's rapid growth which has seen the state's population grow from 9,746,224 in 1980 to an estimated 14,700,000 in 1997. However, stormwater discharges from development existing before 1982 continue to contribute to the degradation of Florida's water resources. This paper will review the institutional framework the state has implemented to address the stormwater problems associated with existing land uses. Its primary focus will be to summarize several different types of urban stormwater retrofitting projects that have been undertaken to reduce pollution from older stormwater discharges. For each project, the type and design of BMP, site characteristics, cost, and pollutant removal efficiency will be summarized.

INTRODUCTION

Florida is blessed with a multitude of natural systems, from the longleaf pine-wiregrass hills of the panhandle, to the sinkhole and sand ridge lakes of the central ridge, to the Everglades "River of Grass", to the coral reefs of the Keys. Abundant surface water resources include over 20 major rivers and estuaries along with nearly 8000 lakes. Plentiful ground water aquifers provide over 90% of the state's residents with drinking water. Add the state's climate and it’s easy to see why many consider the Sunshine State a favored vacation destination and why the state has experienced phenomenal growth since the 1970s. Today, Florida is the fourth most populous state and is still growing rapidly, although not at the rate of 900 people per day (300,000 per year) that occurred throughout the 1970s and 1980s.

This growth has led to increasing urbanization of the state, with the associated clearing and compaction of land, and the creation of thousands of acres of impervious surfaces. Fortunately, Florida's citizens and elected officials became educated about these problems and began developing programs to protect and manage the state's natural resources. Florida began serious and comprehensive efforts to manage its land and water resources and growth coincident with the increasing strength of the environmental movement in the nation and the state during the early 1970s. Over the next 35 years, Florida's natural resources management programs have evolved substantially. Collectively, the individual laws and programs enacted during this period can be considered "Florida's Watershed Management Program”. In many cases, these laws have been integrated either statutorily, with revisions to existing laws, or through the adoption of regulations by various state, regional or local agencies. A primary focal point has been on the

management of nonpoint sources of pollution, especially urban stormwater, since stormwater discharges are responsible for over half of the pollution load entering Florida's rivers, lakes and estuaries.

FLORIDA'S STORMWATER TREATMENT PROGRAM

Research conducted in Florida during the late 1970s characterized stormwater pollutants, provided cost and benefit information on many types of stormwater treatment practices, and determined the importance of stormwater discharges as a major source of pollution. As a result, in 1979, Florida became the first state in the country to require stormwater treatment with the adoption by the Environmental Regulation Commission of the state's first stormwater treatment requirements. In 1982, the state's stormwater rule was fully adopted, requiring all new development and redevelopment projects to include site appropriate BMPs to treat stormwater. This technology-based program establishes a performance standard of removing at least 80% of the average annual post-development loading of total suspended solids for stormwater discharged to most waters. Stormwater discharges to the state's most pristine waters, known as Outstanding Florida Waters, are required to reduce pollutant loading by 95 percent. As a result of the implementation of Florida's stormwater treatment program, the impact of the state's rapid growth on its water bodies has been greatly reduced.

With the successful implementation of Florida's stormwater treatment, wetlands protection, and growth management programs to address the adverse impacts of new development, the focus of Florida's watershed management program has shifted to cleaning up "older sources" such as existing land uses, whether urban or agricultural, and to integrating program components to eliminate duplication and improve efficiency and effectiveness. This has led to greater emphasis on more holistic approaches to address cumulative effects of land use activities within a watershed and to a greater emphasis on regional structural controls and the purchase or restoration of environmentally sensitive lands.

The institutional foundation for Florida's stormwater retrofitting program includes:

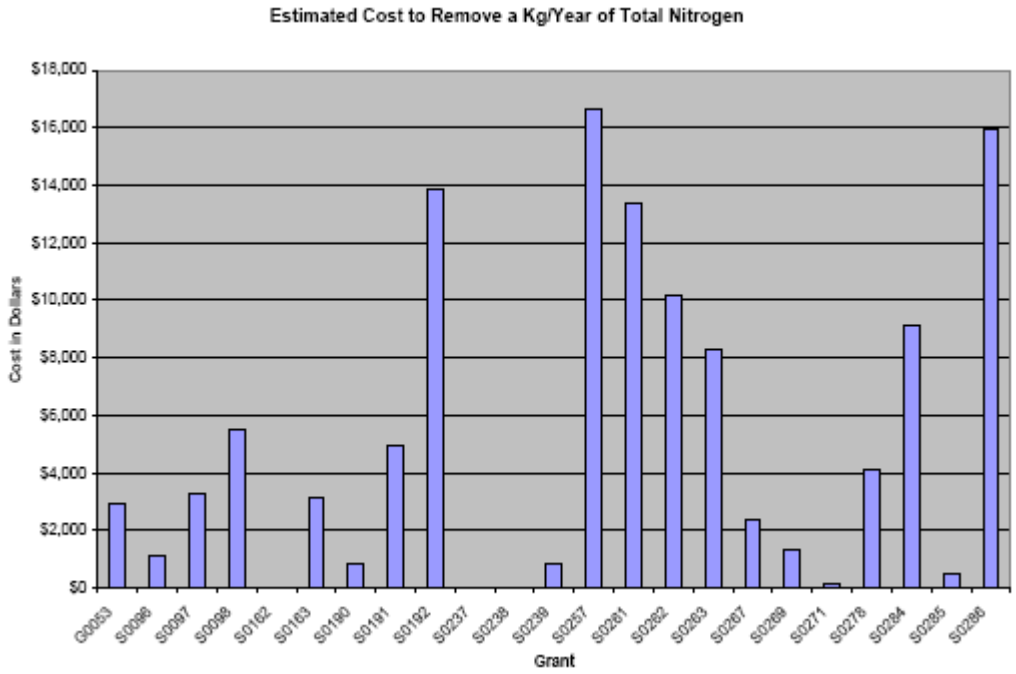
- Adoption of Chapter 403.0893, Florida Statutes, in 1985 providing explicit legislative authority for local governments to establish stormwater utilities or special stormwater management benefit areas. Today, over 140 Florida local governments have implemented a stormwater utility to provide their stormwater programs with a dedicated source of funding.
- Adoption in 1987 of the Surface Water Improvement and Management (SWIM) Act, which establishes six state priority water bodies. It directs the state's five regional water management districts (WMDs) to prepare a priority water body list and develop and adopt comprehensive watershed management plans to preserve or restore these water bodies
- In 1989, the State Nonpoint Source Assessment and Management Plan, prepared pursuant to Section 319 of the Federal Clean Water Act, is submitted to EPA and approved. This qualifies the state for about $8 million annually in Section 319 NPS Implementation grants that are used for BMP demonstration projects and to refine existing NPS management programs.
- In 1989, Chapters 373 and 403, F.S., are revised to clarify the stormwater program's multiple goals and objectives; set forth the program's institutional framework creating a partnership among DER, the WMDs, and local governments; require the elimination of the discharge of inadequately treated agricultural wastewater and stormwater; designates State Water Policy,

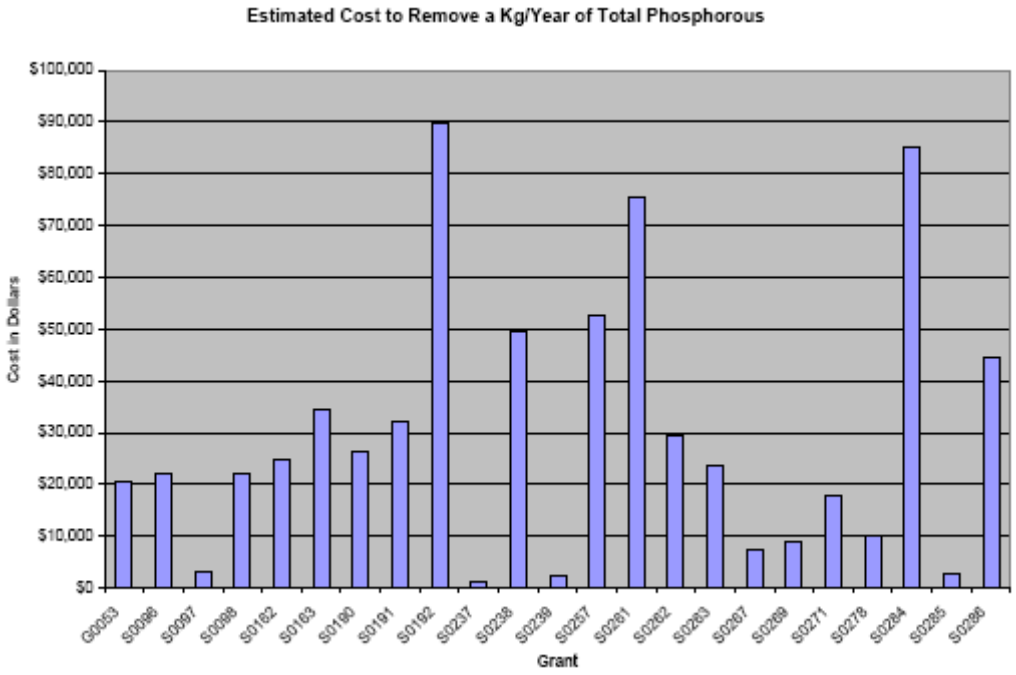
an existing but little used DER rule, as the primary implementation guidance document for stormwater and all water resources management programs; and creates the State Stormwater Demonstration Grant Program with $2 million in funding as an incentive to local governments to implement stormwater utilities.

- In 1990, Chapter 62-40, FAC, State Water Implementation Rule, undergoes a total revision and reorganization so that it can be used as guidance by all entities implementing water resource management programs and regulations. Section 62-40.432 is created and includes the goals, policies and institutional framework for the state's stormwater management program. A major element is requiring the WMDs, who are responsible for preparing SWIM Watershed Management Plans, to include the establishment of stormwater pollutant load reduction goals (PLRGs) to guide stormwater retrofitting efforts. Stormwater PLRGs are defined as the amount of pollutant load reduction from older stormwater systems needed to protect, maintain or restore the beneficial uses of the receiving water body.
- In 1999, the Florida Watershed Restoration Act, Section 403.067, F.S., was enacted providing FDEP with the legal authority to establish and adopt total maximum daily loads (TMDLs) for impaired waters and to equitably allocate required load reductions.
- In 2000, FDEP assumed administration of the federal NPDES Stormwater Permitting program from EPA. This program requires permits for existing municipal and industrial stormwater discharges. Municipal separate storm sewer system (MS4) permits for local drainage systems require pollutant loads to be reduced to the “Maximum Extent Practical”. MS4 permits can be modified to include load reductions established in adopted TMDLs.

URBAN STORMWATER RETROFITTING COSTS

Retrofitting existing urban drainage systems to provide stormwater treatment presents many challenges. These include assessment and prioritization of outfalls to retrofit, finding available land for structural stormwater treatment BMPs, selecting the right BMP to get the highest level of pollutant removal for the pollutant of concern, and funding. The following graphs present the costs per kilogram to remove nitrogen and phosphorus based on projects that have received TMDL Water Quality Restoration Grants.





The rest of this paper will include short summaries of successful urban stormwater retrofitting projects that have been undertaken in Florida. These are representative of the different types of structural BMPs that are being used to reduce the impacts of urban stormwater discharges on Florida's waters. However, it is also important to remember that nonstructural, pollution prevention programs are also a crucial element of urban retrofitting. Educational efforts, whether signs associated with a structural retrofit project or statewide efforts such as Florida Yards and Neighborhoods, are essential in reducing "pointless personal pollution" and in gaining the support of citizens and elected officials for stormwater management programs.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Lake Jackson Megginnis Arm Regional Stormwater System
Northwest Florida Water Management District (NWFWMD, 1984, 1990, 1992)

Watershed Area: 2200 acres

Watershed Land Use:
1191 acres - Low-medium density residential
102 acres - High density residential
469 acres - Commercial
213 acres - Roads
207 acres - Open

Project Overview: Studies in the mid-1970s of Lake Jackson in Leon County, Florida determined that stormwater from the rapidly urbanizing Megginnis Arm watershed and from the construction of Interstate 10 were responsible for the lake's water quality degradation. In 1983, the NWFWMD and the FDER cooperatively designed and constructed, using EPA Clean Lakes grant and state funds, an experimental regional stormwater treatment system. The system consists of a 20 acre wet detention pond with a heavy sediment basin at the inflow, a 4.2 acre sand filter system, and a 5.7 acre, three cell constructed wetland. The pond originally was sized for 150 acre-feet of storage, representing the runoff from a 2.5 inch storm in the watershed. Continued urbanization of the watershed resulted in greater volumes of stormwater thereby reducing the system's effectiveness. Therefore, the system was enlarged in 1989-90 to increase the storage volume by 31.7% thereby providing 173.8 acre-feet of storage, or 1.02 inches of runoff from the watershed. In 1992, the sand filter system was completely renovated including new distribution pipes and sand filter media. Finally, in 1990-92, over 112,000 cubic yards of sediments which had accumulated in the bottom of Megginnis Arm were removed and the littoral areas of the arm were replanted with native macrophytes and trees.

Project Cost:
Original construction - $2,664,389
Pond expansion - $253,643
Educational signs - $19,565
Filter renovation - $80,000
Dredging Megginnis Arm - $990,311
Educational program - $40,000

Educational Component: Educational exhibits were installed at five public boat landings on Lake Jackson to increase public awareness about stormwater pollution, the regional stormwater treatment system, and the dredging project. The NWFWMD created the Teacher's Guide to Stormwater Runoff in the Lake Jackson Watershed and a video entitled "In Search of Old Bigmouth" as resource materials for local teachers. These are used in conjunction with a field trip program for local schools which provides students with "hands on" experience in water quality monitoring and the operation of the regional stormwater treatment system. More than 3,000 students have participated in this program.

Project Evaluation: About 6,000 cubic yards of materials was dredged from the heavy sediment basin after three years of operation with additional material removed during the system's expansion. Monitoring data shows that in normal operation, the system can reduce total volume by 30% and reduce loadings by over 90% for solids, 70% for total nitrogen, 80% for total phosphorus, and 50% for orthophosphorus. (LaRock, 1988).

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Lake Ella Alum Injection System
City of Tallahassee Stormwater Utility (Harper, 1990)

Watershed Area: 157 acres

Watershed Land Use:

13 acres - Residential	15 acres - Open
115 acres - Commercial/Residential	3 acres - Church
11 acres - Commercial	1 acres - Street

Project Overview: In 1985, a lake restoration project was initiated in Lake Ella, a shallow, 13.3 acre hypereutrophic "lake" that receives stormwater runoff from a 157 acre highly impervious watershed. Due to its highly developed and urban watershed, and because of the low permeability of the watershed's clay soils, it was determined that traditional stormwater treatment BMPs could not be used. Instead, chemical treatment of runoff was evaluated using various chemical coagulants including aluminum sulfate (alum), ferric salts, and polymers. Jar tests determined that alum consistently provided the highest removal efficiencies and produced the most stable end product. Consequently, a prototype alum injection system was designed where liquid alum was injected within storm sewers on a flow weighted basis. Standard triplex metering pumps are used as the injection pumps, each individually regulated by sonic flow meters attached to the storm sewer lines to be treated. Many of the smaller storm sewers were combined to reduce the points of discharge into the lake from 17 to ten. Six of these ten inputs, representing 95 percent of the average flow, are equipped with alum injectors. Alum is pumped from a 6000 gallon alum storage tank into individual one inch PVC underground carrier lines to the point of injection. The alum mixes with stormwater as it travels through the storm sewers, passes through a fine mesh trash trap, and is discharged into Lake Ella. The restoration project also included the removal of 50,000 yds^3 of accumulated sand, debris, and muck from the bottom of Lake Ella and the recontouring of the lake's bottom with a gradual slope toward the outfall control structure.

Project Cost: The city's stormwater utility paid $744,000 for the Lake Ella restoration project, with the alum system costing $200,400. At a cost of $137/dry ton of liquid alum, annual chemical costs for alum injection are approximately $10,000 per year.

Project Evaluation: Pre- and post-alum injection monitoring is summarized below:

Parameter	Before	After	Parameter	Before	After
pH	7.41	6.43	DO	3.5 mg/l	7.4 mg/l
Total Nitrogen	1876 ug/l	417 ug/l	Total Phosphorus	232 ug/l	26 ug/l
BOD	41 mg/l	3.0 mg/l	Chlorophyll-a	180 mg/m^3	5.1 mg/m^3
Secchi Depth	0.5 m	2.2 m	Florida TSI	98	47

Alum sludge accumulation rate: 0.33 cm/yr
Pollutants in sediments are much more tightly bound after alum injection system.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Project Smart - Stormwater Reuse Demonstration
City of Winter Park and the University of Central Florida
(Bradner, 1992)

Watershed Area: 8.13 acres

Watershed Land Use: 6.84 acres Impervious Residential/Commercial
1.29 acres Green space
84% impervious with 42% DCIA

Project Overview: Lake Mendsen is a small urban constructed pond which has been altered significantly over many years and also receives untreated urban stormwater runoff. The primary discharge from the pond occurs to two drainage wells. The demonstration project was implemented to try to reduce the amount of untreated stormwater which is discharged to the pond and ultimately the Floridian Aquifer by detaining a portion of the first flush of stormwater so that it can be used for irrigation purposes or "reuse."

An area of the pond (approximately 0.7 acres) which receives stormwater from two existing outfalls was isolated from the main pond by the construction of a berm and weir system. The isolated area serves as a surface water reservoir for the irrigation system. Accumulated sediments and invasive exotic vegetation also were removed from the area and the bottom was recontoured. The resulting littoral zone was planted with five species of native aquatic macrophytes. Instrumentation was installed to monitor rainfall, irrigation pumping rates and volumes, and discharge volumes from the reservoir to the main body of the pond.

Project Cost: The entire project cost $143,000 although capital costs for the irrigation pump and system was only about $4,600.00. Funding for the project was provided by the DER Pollution Recovery Trust Fund ($79,000) and by the city of Winter Park and the University of Central Florida which provide $64,000 in money and in-kind services.

Project Evaluation: A mass balance was performed for the reuse pond over a study period of 358 days. The average irrigation rate for the study period was approximately 1.07 inches per week over the 1.25 acre greenspace. The overall mass balance demonstrated that 55% of the incoming runoff was reused and not discharged into Lake Mendsen. Based on Florida rainfall statistics and stormwater characterization data, this translates into an annual stormwater pollutant load reduction of over 80% for all pollutants. The project also resulted in a real economic benefit. Annualized cost savings for irrigation were calculated to be approximately $3,300.00 per year, based on the reuse of stormwater versus the use of potable water from the City of Winter Park.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Lake Greenwood Urban Wetland
City of Orlando Stormwater Utility (McCann and Olson, 1994)

Watershed Area: 527 acres

Watershed Land Use: 275 acres - Residential
210 acres - Commercial/Industrial
28 acres - Open
14 acres - Water

Project Overview: The Greenwood Urban Wetland was built to alleviate flooding and to treat stormwater runoff prior to discharge to drainage wells which flow to the Floridan Aquifer. The system is designed to detain the runoff from 2.5 inches of rainfall. Approximately 300,000 cubic yards of material was removed to create the system which enlarged the surface area of the "lake" from four to thirteen acres. Weirs were constructed to control water levels and establish three ponds to maximize stormwater detention. The average water depth is 5.1 feet, the storage volume is 66 acre feet, and the hydraulic residence time is 22.7 days. The lakes have a 25 to 30 foot wide littoral shelf which were planted with over 82,000 plants of ten species of native macrophytes. The lakes are connected by marsh flow ways and the system also includes a "riverine floodway" that allows large storms to bypass the lake system. The floodway is planted with seven species of hardwood swamp trees. An upstream sediment/debris basin, pond aeration, and an irrigation system reusing stormwater are incorporated into the design to increase pollutant removal effectiveness. The reuse system allows the City to irrigate the park and the adjacent city owned cemetery with stormwater instead of potable water, saving the city $25,000 per year. In addition to providing flood protection and stormwater treatment, the 26 acre Lake Greenwood Urban Wetland Park includes sidewalks, bridges, and green space passive recreation which is widely used by nearby residents.

Project Cost: $581,000 from the City of Orlando Stormwater Utility.

Project Evaluation: Preconstruction monitoring was conducted from May 19, 1987 through October 13, 1988 to determine the trophic state of Lake Greenwood and to determine the potential loadings discharged to the lake's five drainage wells. The preconstruction Trophic State Index averaged 64 and was highly variable ranging from 12. 5 to 80.8 with five months above 70. After construction, TSI values averaged 57 but no months had values above 66 and variability was less with a range of 36.2 to 66.3. Treatment effectiveness of the system is summarized below:

	TN	NO2	NO3	NH4	TP	OP	Cd	Cu	Pb	Zn
Sed trap	4%	-76%	4%	-100%	11%	7%	26%	19%	10%	6%
Wetland	11%	8%	-13%	10%	62%	77%	0%	59%	60%	69%

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Packed Bed Wetland Filter System
City of Orlando Stormwater Utility
(Orlando Stormwater Utility Bureau, 1995)

Watershed Area: 121 acres

Watershed Land Use: 75 acres - Commercial 18 acres - Roads
14 acres - Stadium/parking 6 acres - Open space
8 acres - Industrial

Project Overview: Clear Lake is 360 acres in size and stormwater loadings from its three square mile watershed have led to serious water quality problems. An innovative stormwater treatment system was needed for this basin to both reduce pollutant load and function within a limited area where multiple demands are placed on the use of land. The constructed experimental stormwater treatment train consists of:

- A 3.3 acre off-line wet detention pond with a sediment trap at the inlet.
- Construction of diversion weirs to shunt the first flush to the wet detention pond while allowing the remaining stormwater to bypass the system.
- Construction of 10 packed beds consisting of five crushed concrete and five granite media beds, vegetated with four differing combinations of wetland plants.
- Installation of two pumps to supply water to the packed beds from both the wet detention system during storms and from Clear Lake during dry periods.
- Control valves to allow for varied water flow rates through the packed beds.
- Automated flow meters and composite samplers to allow storm event sampling.

Project Cost: $917,464 including monitoring costs with funding from DEP through the State Stormwater Demonstration Grant Program and from the City's stormwater utility.

Project Evaluation: Monitoring was performed on the effectiveness of the overall system, the performance of the individual beds, and the best flow rate at which to operate the system (30, 60, or 120 gal/min). Analysis of the individual beds showed consistent removal across all beds for cadmium, copper, lead, zinc, total nitrogen, TKN, nitrite, total phosphorus, TSS, VSS, and fecal coliform. Among the remaining parameters, chromium, ammonia, nitrate, orthophosphorus, TDS, and TOC, pollutant removals within bed 6 were consistently low at all three flow rates. Conversely, bed 5 exhibited consistently high removals for the same parameters. The high flow rate was determined to be the best operating rate for the system. Overall pollutant load reduction is presented below:

Parameter	% Removal	Parameter	% Removal	Parameter	% Removal
Cadmium	80	Total Nitrogen	63	Total phosphorus	82
Chromium	38	TKN	62	Orthophosphorus	14
Copper	21	Ammonia	6	TDS	8
Lead	73	Nitrate	75	TSS	81
Zinc	55	Nitrite	-9	VSS	80
F. coliform	78			TOC	38

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Bath Club Concourse Stormwater Rehabilitation Project
Town of North Redington Beach, Pinellas County, Florida
(Holtkamp, SWFWMD, 1992)

Watershed Area: 2.12 acres

Watershed Land Use: Pre-project - 100% Impervious Roadway/Parking

Project Overview: The Bath Club Concourse is a combination roadway and parking lot connecting Bath Club Circle and Gulf Boulevard. Before the project, the Bath Club Concourse was totally impervious consisting of asphaltic pavement. Untreated runoff from the Concourse and its associated drainage area was directed by sheet flow into a single storm sewer inlet and discharged offsite, and ultimately to Boca Ciega Bay.

The objectives of this project were: (1) to maximize the amount of stormwater runoff that could be infiltrated on-site, thereby reducing the annual volume that is discharged off-site without any treatment; and (2) to demonstrate innovative alternative approaches to treating stormwater in highly urbanized areas where land for traditional BMPs is scarce and very expensive. Drainage was redirected toward two new pervious concrete parking areas located in the center of the Concourse. These are separated by an unpaved landscaping island that also provides infiltration. To maximize infiltration of the pervious concrete parking areas, two 150 feet long underdrains were installed in the eastern half of the project to facilitate the drainage of the subsurface soils immediately beneath the pervious concrete.

Project Cost: Total cost was $147,015 with construction costing $118,380 and landscaping costing $13,345. Funding was provided by a Section 319 NPS grant from DER, the SWFWMD SWIM Program, and the Town of North Redington Beach.

Project Evaluation: The project improvements resulted in a significant reduction of direct discharge of stormwater runoff from the site. Calculations accounting for average annual rainfall and runoff, as well as pore space volume and subsurface water flow, indicate that the improvements caused a 33% reduction in total on-site runoff volume between the pre- and post-project conditions. Further, the volume of surface runoff discharging directly to Boca Ciega Bay was reduced by about 75%. Calculated overall removal efficiencies for the project are based on the efficiency of the underdrain/filter system to remove pollutants and are indicated as follows:

Parameter	Lead	Zinc	TSS	BOD	TP	OrthoP	TN
% Removal	73	72	73	61	49	26	65

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Sunset Drive Outfall Stormwater Rehabilitation Project
City of South Pasadena, Pinellas County, Florida
(Holtkamp, SWFWMD, 1994)

Watershed Area: 49 acres

Watershed Land Use: 21.6 acres - Residential Multifamily
20.1 acres - Commercial
7.4 acres - Residential Single Family

Project Overview: The Sunset Drive drainage basin is nearly fully developed and consists of approximately 55% impervious area. Historically stormwater was collected and discharged untreated to a local storm sewer which connects to a City of St. Petersburg storm sewer main. This storm sewer main ultimately discharges to Boca Ciega Bay.

The objectives of this project were: (1) to reduce stormwater pollutant loading to Boca Ciega Bay by incorporating an in-line sediment sump / oil and grease skimmer in the Sunset Drive storm sewer system, before its junction with the larger storm sewer main; and (2) to demonstrate innovative alternative approaches to treating stormwater in highly urbanized areas where land for traditional BMPs is scarce and very expensive. The sump was designed, to the extent possible, to meet the current rule requirements for this type of system. Due to physical limitations, the design provided for the storm sewer flow to be diverted to the area of an existing greenspace for treatment, prior to being diverted back to the main flow path of the storm sewer. The greenspace, which is adjacent to the bay, was modified into an open, linear wet-sump, which included energy dissipaters and a skimmer baffle. The project also included an attractive boardwalk around and over the facility as well as plantings of salt marsh vegetation in the sump's littoral zone.

Educational Component: The architecture and location of the boardwalk serves to attract pedestrian traffic to the project. Being located immediately in front of City Hall provides an excellent high-profile example of how local government can cooperatively implement measures to reduce stormwater pollution. Several interpretive signs provide information regarding nearshore aquatic plants and animals and the value of stormwater treatment.

Project Cost: Total cost was $115,000.00 with construction costing $83,131. Funding was provided by a Section 319 NPS grant from DER, the SWFWMD SWIM Program, and the City of South Pasadena. A grant from the Tampa Bay National Estuary Program paid for the educational signs.

Project Evaluation: The project provides an opportunity to trap and retain sediment and other suspended materials as small as 0.1 mm in diameter. A corresponding reduction in other urban pollutants typically associated with suspended solids such as heavy metals, bacteria, and oxygen demanding substances can also be expected. The sediment load reduction to Boca Ciega Bay is estimated to be approximately 24.5 cubic yards per year.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

EMS Stormwater Enhancement Project
Pinellas County, Florida
(Holtkamp, SWFWMD, 1994)

Watershed Area: 9.24 acres
Watershed Land Use: 9.24 acres - Mixed Use (85% Impervious)

Project Overview: The original stormwater facility was constructed in accordance with regulations in 1990 to provide stormwater treatment and peak attenuation for the county's new Emergency Medical Services (EMS) complex. The facility discharges indirectly into Boca Ciega Bay. The pond was designed to capture stormwater and treat, using a sand filter encased in a concrete vault, the first half inch of runoff from the entire site. The facility was constructed with 4:1 side slopes, 2 foot average water depth, and a 0.4 foot treatment prism for capturing and filtering runoff. Prior to the enhancements, a monoculture of primrose willow dominated the entire perimeter of the pond.

The primary objective of this project was to demonstrate how stormwater ponds can be designed to enhance their aesthetic and wildlife habitat values while at the same time meeting their intended water quality treatment and/or flood control purposes. The secondary objective was to actually improve the treatment effectiveness of the existing pond by expanding and planting the pond's littoral zone, increasing the treatment volume between the control elevation and overflow weir, and increasing the permanent pool volume, thereby increasing the residence time in the pond.

Educational Component: Due to the adjacent location of the County's Cooperative Extension Service, the project is readily available for touring by anyone visiting the Extension Service. Educational display boxes at various locations along the mulched path surrounding the pond provide information regarding the importance and function of stormwater treatment facilities. Also, as part of the project, the Extension Service produced a twenty-eight minute educational video entitled "Stormwater Ponds: The new Urban Wetlands." While the video discusses the importance of treating stormwater, it focuses primarily on the potential value of stormwater ponds for providing improved urban wildlife habitat. The video is used to inform groups such as homeowner associations, condominium associations, civic associations, etc. about stormwater pollution and management.

Project Cost: Total cost was $78,500 with construction costing $63,244. . Funding was provided by a Section 319 NPS grant from DER, the SWFWMD SWIM Program, and Pinellas County.

Project Evaluation: By more than doubling the permanent pool volume of the pond, the pond's residence time was substantially increased. The pond's treatment volume also was increased by 13.4%, from 0.50 inches of runoff to 0.57 inches. The increased residence time allows for longer periods of physical settling as well as biological activity. The reshaping and replanting of the littoral shelf resulted in increased nutrient uptake.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Jungle Lake Water Quality and Habitat Enhancement
Southwest Florida Water Management District (Macrina and Vickstrom, 1985)

Watershed Area: 390 acres

Watershed Land Use: 7.5 acres - High Density Residential 110.6 acres - Open
84 acres - Commercial 75.6 acres - Low Density Residential 99.9 acres - Institutional

Project Overview: Walter Fuller Park is a highly used recreational/athletic park located in the western part of St. Petersburg, approximately 2.5 miles east of Boca Ciega Bay. Jungle Lake was excavated about 75 years ago to provide fill for the construction of local roads. The 11.2 acre kidney-shaped lake received untreated stormwater from five inflows and discharges to the bay via a single outflow. During most storms, runoff bypassed Jungle Lake and was discharged directly to the bay. To improve the quality of water in the lake and discharge to the bay, a BMP treatment train was constructed consisting of:

- a diversion weir that routs most stormwater into the lake for treatment, not directly to the bay;
- modification of the inflow ditches to create shallow sloughs vegetated with native aquatic macrophytes;
- expansion of the lake to create littoral zones vegetated with macrophytes;
- two partially submerged berms which produce a longer flow path, increase residence time, provide natural habitat, and replace park uplands lost by lake expansion ;
- sediment sumps at the northeastern and southeastern inflows;
- an oil and grease skimmer on the outfall structure;
- over 15,000 herbaceous plants consisting of 11 species, 170 trees, and 700 shrubs.

Project Cost: $600,000 that included $55,000 from the City of St. Petersburg and $545,000 from the SWFWMD SWIM Program. About 51,000 cubic yards of fill were needed for the project. Instead of importing fill at a cost of $3.80 to $4.75 a cubic yard, the area northeast of the lake, which was three feet higher than surrounding areas, was excavated. Within this area, two soccer fields were designed and constructed to provide the community with additional recreational facilities and to promote park usage. Even after the sodding of the soccer fields and the installation of an irrigation system, over $35,000 was saved from original costs for fill.

Educational Component: The City and SWIM staff met with members of the Jungle Lake Civic Association to obtain their input and to extend their ownership of the park to include the stormwater improvements. The members assisted in the selection of plants, received a grant to supplement the wetland and forest plantings, assisted in planting the vegetation, and are participating in the educational, maintenance, and monitoring aspects of the project. The site has eight educational displays that inform the general public and students about stormwater issues and management. A teacher's manual was produced that can be used in the classroom or to accompany the signs during school field trips.

Project Evaluation: The project greatly improved water quality within Jungle Lake and in the water discharged downstream. Average reductions in concentrations and mass loading discharged from the lake after the project are summarized below.

	TN	NH4	TP	OP	Cd	Cu
Concentration	28%	73%	39%	46%		
Loading	-1%	82%	54%	33%	81%	69%

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Oleander Avenue Stormwater Exfiltration Trench System
City of Daytona Beach, Florida
(CDM, 1994)

Watershed Area: 49 acres

Watershed Land Use: Single Family Residential -
23% Directly Connected Impervious Area (DCIA)

Project Overview: The Oleander Avenue watershed historically discharged untreated runoff to storm sewers that ultimately discharged to the Halifax River. The area was also subject to periodic local flooding due to the inadequate capacity of the conveyances. The primary objective of this project is to demonstrate the cost-effectiveness of using exfiltration systems as a method of retrofitting stormwater problem areas for future use within the City's beachside community.

To alleviate the flooding problem and to reduce pollutant loading to the river, a perforated pipe exfiltration trench treatment system was constructed. Site constraints limited the treatment volume to 0.75 inches over the DCIA which translates into a storage volume of 30,700 cubic feet. The 294 feet of exfiltration system is designed to accept the runoff from a 5 year, 24 hour storm representing flows of from 1.5 to 17.5 cfs from the drainage area subbasins. Actual pipe sizes varied from 19" x 30" to 29" x 45" to meet the design storm flow conditions. The rock filled trench measures 16 feet in width and 2 feet in depth.

Project Cost: Total cost was $513,700.00 with construction costing $375,617. This represents a cost of approximately $10,200.00 per acre. Funding was provided by DEP from a State Stormwater Demonstration Grant and from the City of Daytona Beach.

Project Evaluation: The exfiltration trench appears to be functioning very well as water quality monitoring efforts have failed to find any discharge from the system. Since exfiltration systems provide 100% treatment for all water that is retained and exfiltated, this system will reduce the stormwater pollutant loadings discharged to surface waters by at least 80% since the trenches will eliminate the discharge from over 80% of the storms that occur. The project allowed the City to identify the design and construction constraints associated with this type of treatment system as well as installation costs for these systems. This knowledge will be used as the City retrofits other basins.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Indian River Lagoon Baffle Boxes
Brevard County Surface Water Management (England, 1997)

Project Overview: The Indian River Lagoon National Estuary Program identified stormwater discharges as the major factor in the decline in the lagoon's health. In particular, reductions in the stormwater loadings of total suspended solids, nutrients, and freshwater are needed to restore the lagoon. The county developed an innovative BMP, the baffle box, which can be installed within existing rights-of-way as a way of retrofitting stormwater discharges where land is unavailable for traditional BMPs. Baffle boxes are large sediment traps that require regular maintenance. Sediment accumulation rates vary depending on site characteristics such as drainage area, land use, soil type, slope, mowing frequency, base flow, etc. The boxes accumulate from 500 to 50,000 pounds per month with cleaning required monthly in the wet season and every two to three months in the dry season. By the end of 1997, the county had installed thirty one baffle boxes with others under construction. As part of the implementation of the Indialantic area stormwater master plan, eleven baffle boxes currently are being installed and monitored. Three different designs are being evaluated to determine their effectiveness including: (1) a two chamber box for small pipes and drainage areas; (2) a three chamber box for larger pipes; and (3) two boxes in series where one box currently exists and collects large amounts of sediment.

Project Drainage Area and Cost: The average cost of installing a baffle box is around $22,000 and the average clean out cost is $450 (by private contractor). Funding from a Section 319 NPS grant from DEP and from the County's stormwater utility are paying for the Indialantic projects. These all serve mainly residential land uses, and the construction costs and watershed drainage area are summarized below:

Project	Drainage area	Cost	Project	Drainage area	Cost
Alamanda	1.8 acres	$14,376	Franklin (2)	36 acres	$33,362
Rivershore	7.2 acres	$ 9,463	Riverside	161 acres	$24,944
Indialantic I	25 acres	$13,580	Sunset Park	24 acres	$23,422
Monaco	54 acres	$32,835	Puesta Del	2.2 acres	$25,181
Pinetree	134 acres	$33,925	Cedar Lane	0.9 acres	$25,027

Project Evaluation: The monitoring program for the eleven new baffle boxes will not begin until the spring of 1998. However, previous assessments of the effectiveness of baffle boxes on 22 existing systems is shown below:

BMP	Number Installed	Number Cleanouts	Total lb. Removed	Ave. lb. Per Cleanout	Avg. Cost per Cleanout	Cost/lb. Removed
Baffle box	22	127	606,243	4774	$426	$0.09

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Oil and Grease Removal BMP Demonstration
City of Oakland Park, Florida (CDM, 1995)

Watershed Area: 5 acres

Watershed Land Use: Mixed commercial and industrial (95% Impervious)

Project Overview: The City of Oakland Park received one of the state's Stormwater Demonstration grants to develop and monitor a prototype BMP for in-line removal of oil and grease from stormwater, using oil absorbent material. The Northeast 40th Court site was chosen because inspection of the storm sewer system revealed substantial amounts of oil and grease. These were attributed to the large number of automobile repair shops, paint shops, plating shops, and similar businesses in the drainage area. The project consisted of characterizing the concentrations of oil and grease in the stormwater, a review of the material safety data sheets of three different oil sorbent materials, a laboratory bench scale study of one of the oil sorbent materials, construction of the BMP system, and effectiveness monitoring. The final BMP system included diversion box with a weir to direct runoff into the treatment system. As stormwater enters the treatment unit, flow is directed against an aluminum baffle imparting a slight rolling motion that causes floatables and trash to be trapped against the baffle wall for easy removal. Upon entering the treatment chamber, velocity slows greatly allowing grit, sludge, and oil particulate matter to settle to the sloping bottom. The stormwater is then redirected upward through two cross-layers of the absorbent media which are secured by being sandwiched between two aluminum grates, where free oil and grease are removed via absorption onto the material. The absorbent media chosen was custom made by NewPig Corporation of Tipton, Pennsylvania. The product, called the Spaghetti Pillow, consists of shredded strips of polypropylene packaged in tough, UV resistant mesh skin in the shape of a rectangular bag or pillow. The two layers of media are placed perpendicular to each other to avoid short circuiting.

Project Cost: Total cost of the project was $260,870. This included $71,490 for the construction of the treatment system and $189,380 for sampling equipment, consultant and laboratory fees.

Project Evaluation: Inflow and outflow sampling of the system was conducted for ten storms between July 1994 and April 1995. Storm event oil and grease concentrations ranged from 0 to 261 mg/l with mean pollutant concentrations ranging from 1.41 to 85.58 mg/l. Oil and grease mass removal efficiencies ranged from 71% to 95% while flows ranged from 0 to 1.75 cfs. The absorption efficiency of the filter media bags were measured twice. The amount of oil and grease absorbed ranged from 1.7 pounds to 62.5 pounds which represents an absorption efficiency of 110% to 470%.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

BMP Treatment Train in the Florida Keys
City of Key Colony Beach, Florida (Greiner Engineering, 1993; ERD, 2002)

Watershed Area: 268 acres of single and multifamily residences and streets

Project Overview: Recognizing the importance of reducing stormwater pollution in protecting its sensitive natural resources, the City included in its comprehensive plan policies requiring the retrofitting of its existing drainage system. With technical assistance from the DEP and the SFWMD, the City's consultant developed a stormwater master plan in 1993. The plan included the plugging of 28 existing stormwater outfalls and the construction of a retention basin and swales with raised inlets and exfiltration trenches which overflow into injection wells. Implementation of the master plan began in 1995 and is scheduled for completion by the year 2000. Phase 1 has been completed and Phase 2 will be completed by the fall of 1998. The stormwater master plan calls for the construction of 82,146 linear feet of swales, 9 modified raised swale inlets, about 60,000 linear feet of exfiltration trench, 35 inlet baffle systems to direct the first flush into the exfiltration trenches, and 22 injection wells.

Project Cost: The total cost of the original stormwater retrofitting master plan was estimated to be $1.2 million. However, the city's residents and elected officials decided that they did not want water standing in the swales, resulting in the addition of the exfiltration trench system. To date, using funds from the city, the DEP, and a Section 319 grant the city has implemented two phases of the master plan as shown below:

Basin	Acres	Swale (lf)	Sod (sf)	Exf. Trench (lf)	Injection Wells	Cost
4-1	0.66	827	29,257	445	1	$ 72,200
5-2	3.03	521	21,304	269	0	$ 47,083
2-2	3.50	1,200	14,000	1,200	1	$148,112
2-5	3.00	1,200	14,000	1,200	1	$147,790
2-8	2.13	934	11,000	934	1	$129,600
2-11	1.76	566			1	$ 27,854
3-1	3.69	878	11,000	878	1	$113,175
5-1	26.47	4,800	37,000	3,100	3	$439,773
8-2	0.02	1,306	371	371	1	$ 72,174

Project Evaluation: Field monitoring of the components of the BMP Treatment Train was conducted between July 2001 and November 2002. Mass removal in the dry detention system was observed for only a few parameters while mass increases occurred for particulate nitrogen, nitrate-nitrite, total nitrogen, total phosphorus, and dissolved orthophosphorus. This poor performance was related to the hydrologic and chemical characteristics of the shallow ground water in the area. During rain events, the ground water rises up into the pond at the same time as runoff is entering the pond. The same factors minimized the effectiveness of the swale system.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Salerno Creek StormWater Retrofit
Martin County Office of Water Quality (2005)
Ecological Associates, Inc (2005)

Watershed Area: 600 acres

Watershed Land Use: Subdivisions/Single Family Residential

Project Overview: This project consists of construction of a wet detention area with an extensive littoral zone that also serves as a park that will capture runoff from a 600 acre highly urbanized area within the City Of Stuart in Martin County. The 21 acre pond has a 50 feet wide littoral zone on its entire perimeter with extensive wetland plants. The treatment storage volume is 54 acre-feet or about 0.75" of runoff from the drainage area. A 900 feet long sheet pile structure was used to prevent short circuiting between one of the inflows and the discharge structure. The project was a cooperative effort among several groups including Martin County, FDEP, South Florida Water Management District, FDOT, and the University of Florida's Institute of Food and Agricultural Sciences (IFAS). The project area known as Manatee Pocket "Sub-Basin 4 is the most highly developed and least treated drainage area contributing stormwater to the Indian River Lagoon. The area includes 28 subdivisions and 1,550 single-family homes, developed before present water quality regulations. The goals of this regional detention facility are to attenuate and remove solids, nitrates and heavy metals.

Project Cost: Total cost of the project was $2,142,988 with FDEP providing $475,000 in a Section 319 Nonpoint Source Implementation Grant.

Project Evaluation: Results of the post-construction water quality effectiveness monitoring indicate that all analytes tested (TKN, NOx, TN, TP, Cu and TSS) decline after treatment in the wet detention system. Some of the more notable reductions were nitrite/nitrate (NOx; 87% reduction), copper (58% reduction) and TSS (31% reduction). Phosphorus was completely eliminated from stormwater treated by the STA while DO increased by 23%. Nitrogen parameters were reduced slightly more during the dry season (28% vs 10% in the wet season), probably due to the longer residence times within the STA during the dry season. Additionally, the stormwater treatment system allows infiltration reducing the total volume of stormwater discharged to Salerno Creek.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Golden Gate Stormwater Retrofit
Martin County Office of Water Quality (2005)
Ecological Associates, Inc (2005)

Watershed Area: 242 acres

Watershed Land Use: 620 single family homes plus a small commercial area along US 1

Project Overview: The project was designed to reduce the volume and improve the quality of stormwater entering the St. Lucie River Estuary from the Golden Gate drainage basin in Martin County, Florida. The basic design concept behind the Golden Gate project was to direct and channel stormwater through a BMP treatment train. The train starts with the collection of stormwater in baffle boxes which capture floating litter and solids before the water is channeled via culverts into the Dry Detention Areas. There, stormwater volumes are attenuated by control structures with bleeders before the water passes via culverts to the STA where up-take of nutrients occurs. After passing through the entire treatment train, "polished" stormwater is discharged via control structures to receiving water bodies.

Separate stormwater treatment facilities were constructed to serve the northern and southern portions of the drainage basin, with the Hemlock Ditch connecting the northern and southern components. The northern basin treatment train includes a baffle box, a 2.7 acre dry detention system, and an 8.7 acre STA that provides 9.2 acre feet of stormwater treatment volume. The southern basin treatment train consists of a baffle box, a 2.0 acre dry detention area, and the 8.7 acre STA providing 8.3 acre-feet of treatment volume. The overall project provides 17.5 acre-feet of stormwater treatment volume which equates to one inch of treatment for the entire drainage area.

Project Cost: Total cost of the project was $2,002,149 with FDEP providing $440,000 in a Section 319 Nonpoint Source Implementation Grant. Project costs included:

Task	Grant Funds	Local Funds	Total Costs
Design		$246,560	$246,560
Land Acquisition		$552,534	$552,534
Construction	$399,565	$752,990	$1,152,555
BMP Monitoring	$ 40,435	$ 65	$ 40,500
Education		$ 10,000	$ 10,000
Total Costs	$440,000	$1,562,149	$2,002,149

Project Evaluation: The northern component generated pollutant load reductions for TP and TN of 82% and 44% respectively, leading to annual nutrients load reduction of 62 Kg/yr for TP and 262 Kg/yr for TN, along with and annual BOD reduction of 910 Kg/yr.

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

McIntosh Park Enhanced Stormwater Treatment Wetland Project
South Florida Water Management District (Various dates)

Watershed Area: 6,288 acres of mixed, older development without stormwater treatment

Watershed Land Use:

Land Use	**Existing Land Use (acres)**	**Percentage of Total**
Parks, Recreation, & Open	1,525	24%
Cultivated/Rural Agriculture	1,324	21%
Low Density Residential	344	6%
Medium Density Residential	903	14%
High Density Residential	273	4%
Public/Semi-Public/Institutional	73	1%
Commercial	399	6%
Industrial	129	2%
Transportation	359	6%
Natural/Preservation/Wetlands	737	12%
Watercourses/Waterbodies	222	4%
TOTAL	6,288	100%

Project Overview: This project consists of two phases. Phase 1 is a wetland restoration project to restore a diched and drained 100 acre forested wetland. The Phase 2 BMP treatment train includes sediment sumps, wet ponds, and wetlands treatment. Additionally, an alum injection system was added downstream of the final wetland to provide final treatment. McIntosh Park is a 375 acre passive activities park managed by the City of Plant City and purchased through a public land purchase program. The wetland treatment system will be used to treat stormwater runoff and baseflow from the 6,288 acre watershed. The treatment volume of the system is 115 acre feet of runoff which is approximately 1.75 inches over the entire watershed. Water from the Eastside Canal is diverted into the system for treatment. Additionally, 39 acres of new wetlands will be created by the project. The project will provide significant pollutant load reduction for stormwater runoff from the Eastside Canal a Tributary to the Itchepackasassa and Blackwater Creeks, the Hillsborough River, Hillsborough River Reservoir and Tampa Bay.

Project Cost: Total cost of the project was $1,901,159 with FDEP providing $699,872 in a Section 319 Nonpoint Source Implementation Grant.

Project Evaluation: This project includes an extensive monitoring program to better understand the benefits of each component of the BMP treatment train, especially the wetland cells which have been planted with different species of aquatic macrophyte plants. Monitoring is ongoing. Anticipated load reduction from this project is 42% nitrogen, 77% phosphorus and suspended solids and 64% BOD.

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URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Kapok Wetland and Floodplain Restoration
City of Clearwater
(NPS Grant Work Plan and Progress Reports)

Watershed Area: 4533 acres of mixed, older development without stormwater treatment

Watershed Land Use:

LAND USE	Area (ac)	LAND USE	Area (ac)
Agricultural	20.64	**Low Density Residential**	310.16
Commercial	639.95	**Medium Density Residential**	78.56
High Density Residential	1923.67	**Open Land**	104.29
Highway/Utility	245.72	**Recreational**	103.42
Institutional	316.86	**Natural Areas**	365.50
Industrial	232.82	**Water**	191.55
Total Acres	**4533.14**		

Project Overview: The project consists of the restoration of a 37 acre developed site to its predevelopment condition to provide floodplain storage, stormwater treatment and wildlife habitat. The city of Clearwater purchased the 37-acre site, formerly a mobile home park, for the sole purpose of implementing this project. The project consists of the removal of an upstream control weir, construction of a new weir structure at the downstream reach of Alligator Creek on the Kapok property to divert water into the wetland, and restoration of the property to its predevelopment condition. The project will create approximately 20 acres of wetland habitat. The estimated runoff treatment depth for the contributing portion of the Alligator Creek Watershed to the project area was calculated to be only 0.075 inches, assuming a maximum BMP depth of 1.5 feet.

Project Cost: Total cost of the project was $9,638,636 with multiple funding partners

ACTIVITY	Project Cost
Property Purchase	$7,323,500
Engineering Design/Construction Services[1]	$315,136
BMP Implementation (Construction)	$1,950,000
BMP Effectiveness Monitoring	$50,000
TOTAL PROJECT COST	**$9,638,636**
Percentage of Total Project Cost	

Contributor	Amount
City of Clearwater	$7,323,500
SWFWMD-SWIM Trust Fund	$1,089,082
SWFWMD - Pinellas-Anclote River Basin Board -	$726,054
FDEP Section 319 grant	$500,000
Total Non-Federal	**$9,638,636**

Project Evaluation: The project is anticipated to reduce TSS by 23,850 pounds per year. Monitoring currently is ongoing to determine the system's treatment effectiveness. The system also will serve as a park where displays will be constructed to educate the public about stormwater pollution and treatment.

Modeled loads and load reductions:

	TN	TP	BOD_5	TSS	Pb	Zn
Estimated Gross Load (lbs./year)	28,634.9	6,483.6	283,260.3	424,012.6	86.7	613.2
Estimated Load Removed (lbs./year)	**644.3**	**291.8**	**10,622.3**	**23,850.7**	**4.9**	**27.6**

URBAN STORMWATER RETROFITTING PROJECT FACT SHEET

Riverfront Park Stormwater Project
Quentin L. Hampton Associates, Inc (2003)

Watershed Area: 12 acres of mixed, older development without stormwater treatment

Watershed Land Use:

LAND USE	Area (ac)
Commercial	8.1
Roadway	3.9
Total Acres	**12.0**

Project Overview: Cocoa Village is located on land that was created in the mid-1950s by constructing a bulkhead and dredging fill from the Indian River Lagoon. The development consisted almost entirely of impervious areas with untreated stormwater discharged directly to the Lagoon through seven storm sewers, three of which run through the project site. Project objectives were to reduce stormwater pollutant loadings to the IRL, to increase the available supply of reclaimed water, and to educate the public about stormwater pollution and abatement. The BMP treatment train consists of a baffle box on each storm sewer, underground storage pipes that store 0.50 to 0.75 inches of stormwater, and a pump system that routes the pre-treated stormwater to the city's wastewater treatment system at night where it becomes part of the city's reclaimed water supply. A rainfall event of 1.12 inches or more is required to fill the underground storage system. The system also will serve as a park where displays will be constructed to educate the public about stormwater pollution and treatment.

Project Cost: Total cost of the project was $503,588 with FDEP providing $197,460 in a Section 319 Nonpoint Source Implementation Grant.

Project Evaluation: Unfortunately, problems with monitoring equipment, especially the flow meters, negated the BMP effectiveness monitoring program. Instead, modeling of the system using data derived from the monitoring program was used to determine the project's load reductions. Listed below is the projected load reductions from the project

Modeled loads and load reductions:

	TN	TP	BOD_5	TSS
Estimated Load Removed (lbs./year	96	12	576	3457

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