Tampa Bay Estuary Program
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# DEVELOPMENT OF SEDIMENT CONTAMINANT LOADING ACTION PLAN

## FINAL REPORT

March 1999

**Development of Sediment Contaminant Loading Action Plan**
T-96-03

*Prepared for:*

**TAMPA BAY NATIONAL ESTUARY PROGRAM**

St Petersburg, Florida

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## EXECUTIVE SUMMARY

The Tampa Bay National Estuary Program (TBNEP) Toxic Contamination Sources Assessment project was initiated to identify specific sources of contaminants and to prioritize management actions based on risks associated with the contaminants in areas of Tampa Bay. The overall project consists of three distinct tasks, namely:

Task 1: Risk Assessment for Chemicals of Potential Concern and Methods for Identification of Specific Sources

Task 2: Sources of Sediment Contaminants of Concern (COCs) and Recommendations for Prioritization of Hillsborough and Boca Ciega Sub-Basins

Task 3: Development of Sediment Contaminant Loading Action Plan

This report focuses on Task 3 of the overall project. Task 1 of the Assessment project included an evaluation of ecological and human health risks associated with sediment contaminants in areas of Tampa Bay, and development of a methodology for specific source identification. Areas evaluated for Task 1 included upper and lower Hillsborough Bay, McKay Bay, Boca Ciega Bay, Bayboro Harbor, and western Old Tampa Bay.

Based on previous studies evaluated by TBNEP and the results of Task 1 of the Assessment project, the lower Hillsborough River, coastal Hillsborough, and Boca Ciega drainage basins were considered priority areas for evaluation of toxic contaminant releases. The focus of Task 2 of this Assessment project was to identify specific sources of Contaminants of Concern (COCs) in the priority drainage basins, to estimate loadings by these sources, where possible, and to prioritize sub-basins for management actions.

Based on these efforts, Delaney Creek was identified as the priority sub-basin in the upper Hillsborough Bay watershed; whereas, Long Bayou was the priority sub-basin identified in Boca Ciega Bay watershed. The sub-basins were ranked based on total loading (point and non-point discharges) of the COCs.

The study reported herein, Development of Sediment Contaminant Loading Action Plan, was the next task (Task 3) in the overall Assessment project. This study attempted to identify Best Management Practices (BMPs) that can be successfully integrated into Action Plans, developed and implemented by local governments and agencies participating in the TBNEP, specifically in the two priority sub-basins. This study also attempted to identify and correlate current and past land uses in the priority sub-basins with sediment contamination as identified in the Bay area.

Personnel from various state and local agencies, as well as local industries and municipalities, were contacted in each of the two priority sub-basins. It was evident that most COCs have been controlled by various water management regulations (NPDES, Water Management District, FDEP) over the past 10 years and this trend is expected to further improve as we move into the next millenium. Some of the key observations made during the study include:

- Existing stormwater management facilities appear to be adequately maintained and the best opportunity to improve stormwater quality exists during construction and redevelopment activities.

- Street sweeping effectiveness is currently being evaluated by FDOT and the City of Tampa as an efficient means to improve run-off water quality.

- Public Education projects are effective in promulgating environmental consciousness amongst citizens and are a cost effective approach.

- The Underground Storage Tank (UST) identification efforts were completed for only Long Bayou. However, it is obvious that efforts in clean up must continue as 75 percent of the facilities were identified as having evidence of contamination. Funding sources for clean up is and will continue to be an issue.

- Regional opportunities to treat runoff stormwater quality exists, but are very expensive. Innovative approaches such as offering credit (Monetary or Water Quality credits) to industry for retrofit or similar water quality improvement alternatives work well, especially when coupled with stormwater utilities and the need to satisfy Total Maximum Daily Load (TMDL) targets.

A field reconnaissance effort, particularly in Delaney Creek, revealed that several of the point sources of COCs were either present but no longer in operation, physically no longer present, or incorrectly identified in this sub-basin. This suggests a need to improve the accuracy of existing databases before similar efforts are initiated in other sub-basins.

Available sediment chemical data, particularly from Delaney Creek, indicate that past industrial and land use activities are a contributing factor to the currently observed contamination of sediments in this sub-basin. The fine-grained or organic-bearing sediments contain much higher concentrations of contaminants than the sandy sediments. Sediment data from water bodies in both sub-basins also suggests that these organic sediments could be a source of contaminants for the overlying water.

Chemical data specifically from Delaney Creek suggests that the "cleaner" surface sediments may effectively "cap" the deeper contaminated sediments. However, disturbance of the surface sediments could expose the contaminated sediments that could then impact the benthic community. Dredging is a viable option for removing these sediments. Dredging is being considered for Lake Seminole, in Pinellas County and other water bodies such as Lake Maggiore in St. Petersburg and Stevenson Creek in Clearwater. Innovative, yet feasible techniques in dredging have been used in the Indian River Lagoon and continue to be used to improve water quality in that estuary. Similar dredging opportunities should be considered for the Tampa Bay Estuary.

It was evident after several meetings and conversations with the municipalities, regulatory agencies, and various environmental groups that a more coordinated clean-up effort needs to be initiated to discuss, select, and target particular sub-basins within the Tampa Bay region. This would also be beneficial in terms of optimizing the use of available resources (both monetary and labor).

# 1.0 INTRODUCTION AND APPROACH

## 1.1 Introduction

The contribution of sediments and Contaminants of Concern (COCs) as influenced by past activities to Tampa Bay and its watershed is an unresolved issue. This factor will greatly influence the level of effort that is placed on managing the various sources of COCs. In order to address this issue, the Tampa Bay National Estuary Program (TBNEP) Toxic Contamination Sources Assessment project was initiated to identify specific sources of contaminants and to prioritize management actions based on risks associated with sediment contaminants in Tampa Bay. TBNEP activities to assess sediment contamination risks in Tampa Bay were initiated through an inventory of sources of contamination (Frithsen et al., 1995). This was followed by a data synthesis and mapping analysis to characterize Tampa Bay sediment contamination (Zarbock et al., 1996). The deposition and occurrence of trace metals in Tampa Bay was further investigated by TBNEP through studies of atmosphere deposition (Dixon et al., 1996) and sediment testing (Grabe, 1997). This work added to previous sampling and analysis by FDEP and others. Based on these studies, areas of the watershed were targeted as critical for controlling contaminant inputs to the bay. The lower Hillsborough River, coastal Hillsborough bay, and Boca Ciega Bay drainage basins were identified as priority areas for evaluating the contaminants and their release (McConnell et al. 1996). Parsons Engineering Sciences, Inc. (1997) also identified specific contributors of COCs, estimated their loadings by sources, and prioritized the sub-basins for management actions. This process resulted in Delaney Creek being reported as the priority sub-basin in the upper Hillsborough Bay watershed and Long Bayou as the priority sub-basin in Boca Ciega Bay watershed. The sub-basins were ranked based on total loading (point and non-point discharges) of the COCs.

The study reported herein, Sediment Contaminant Loading Action Plan, is the next task in the overall Assessment project. The results of this study will be used to identify management practices that can be successfully integrated into Action Plans developed and implemented by local governments and agencies participating in the TBNEP, specifically in the two priority sub-basins. This study also attempted to identify and correlate current and past land uses in the priority sub-basins with sediment contamination as identified in the Bay area.

## 1.2 Objectives

BCI Engineers and Scientists, Inc. was contracted by the TBNEP to complete the final task under the Toxic Contaminant Sources Assessment project. The goal of this task was to develop a Sediment Contaminant Loading Action Plan that can be successfully incorporated into the local Action Plans being developed by local governments and agencies participating in the TBNEP. To meet this goal, two specific objectives were outlined.

- *Identify Specific Projects or Management Action that are Currently Underway or Planned Within Selected Priority Sub-basins*

The key to this objective was to identify and, if needed, develop specific projects or management actions within each of the two selected priority sub-basins that drain into Tampa Bay. This objective also assessed the influence of currently implemented management actions and the resulting sediment and chemical loading into the Bay.

- *Identify and Correlate Current and Past Land Uses in the Priority Sub-basins With Sediment Contamination as Identified in the Bay Area*

An attempt was made to correlate sediment contamination as reported in the Bay with loading resulting from "current" management actions and existing land uses within each priority sub-basin. This objective determined whether sediment contamination in the Bay has been influenced by changes in management actions and land use.

The above two objectives attempted to address two specific questions. The first was *"what are the current projects or management actions in the priority sub-basin(s) that are functioning effectively to reduce sediments and contaminant loading to the Bay?"* Secondly, *"is the current land use indicative of the observed sediment contamination or is the contamination being reported in the Bay a remnant of past management actions and land uses?"* The answers to these questions could identify flaws or effectiveness of the land use management actions and enable implementation of corrective actions that are central to the Tampa Bay Comprehensive Conservation and Management Plan (CCMP).

## 1.3 Project Approach

The approach utilized for this study focused on identifying and targeting management plans that are thought to contribute to and reduce sediment and chemical loading to the bay from each priority sub-basin. This information was in turn used to help evaluate and propose effective strategies to reduce or preclude discharges of the previously identified COCs (pesticides, PCBs, HPAHs, and metals).

The following in a synopsis of the methodology used to address the first objective of this project.

- Identify the priority sub-basin in the Hillsborough Bay watershed and Boca Ciega drainage basin from the Toxic Contamination Sources Assessment: Sources of Sediment Contaminants of Concern and Recommendations for Prioritization of Hillsborough and Boca Ciega Sub-basins report (Parsons Engineering Sciences, Inc., 1997).
- Meet with various municipalities within each sub-basin and other regulatory agencies to generate information on compliance for the various facilities (sources) identified for the specific COCs.
- Initiate a field reconnaissance effort to verify the location of various point sources identified in the previous report (Parsons Engineering Sciences, Inc., 1977).
- Initiate a field reconnaissance effort to identify and characterize various pollutant control structures and strategies that have already been implemented at various facilities or implemented by municipalities.
- Identify point and non-point sources contributing to the existing contaminant loading within the priority sub-basins including stormwater management areas and underground storage tank sites.
- Evaluate willingness of the responsible parties to participate in identifying additional controls.
- Identify any existing management plans such as NPDES programs being implemented by municipalities and FDOT District VII.
- Identify existing and on-going, non-structural management practices such as public education.

- Evaluate data generated from above management programs and establish the overall cost and pollutant removal effectiveness.

The following is a synopsis of the approach used to address the second objective of this project.

- Evaluate sediment data specific to the two sub-basins and determine if they are a source of contaminants. Existing areas of high sediment contamination will fall generally into several categories:
  - contamination present, source identified, contaminant continues to be generated at high rates.
  - contamination present, source identified, contaminant generation significantly reduced.
  - contamination present, likely historical source identified, contaminant no longer generated.
  - contamination present, no definite source identified, contaminant no longer generated.

These categories will serve to identify whether source controls can potentially be implemented to reduce COC loadings or whether the existing sediment contamination is the sole remaining problem. The action plan development effort focused on contaminants correlated to existing, active sources that are amenable to further reduction. Finally, approaches such as dredging that may be implemented for removing and disposing of contaminated sediments was evaluated.

# 2.0 CHARACTERIZATION OF EXISTING CONDITIONS

## 2.1 Priority Sub-Basin and Contaminant Source Identification

### 2.1.1 Contaminants of Concern

Potential ecological and human health risks related to sediment contaminants in Hillsborough and Boca Ciega Bays were evaluated during Task 1 of the Toxic Contamination Sources Assessment project (McConnell et al., 1996). Risks due to sediment contaminant exposure were evaluated by comparing potential exposures to toxicity values for representative ecological indicator species and human receptors. These comparisons allowed an estimation of the likelihood of adverse effects occurring as a result of exposure of the receptors to specific chemicals.

As part of the risk characterization for sediment contaminants, the following criteria were used to identify specific chemicals as COCs: 1) estimated exposures represented a significant potential for adverse effects based on the magnitude of exceedance of the risk threshold, 2) the number of receptors affected, 3) the frequency of contaminant detected, and 4) the uncertainty associated with components of the risk estimated. Table 1 (Parsons Engineering Sciences, Inc., 1997) shows the COCs in the two major basins.

The overall objective of the Toxic Contamination Sources Assessment project (Parsons Engineering Sciences, Inc., 1997) was to identify sources of COCs in the priority drainage basins, to estimate loadings by these sources where possible, and to prioritize sub-basins for development of management actions. Point sources and non-point sources including stormwater runoff and atmospheric deposition were evaluated to determine the fraction of the total COC loads attributed to each source type.

**Table 1**
**Summary of Sediment Contaminants of Concern**
**In Upper Hillsborough and Boca Ciega Bays***

| Chemical | Upper Hillsborough Bay | | Boca Ciega Bay | |
|---|---|---|---|---|
| | **Ecological[(1)]** | **Human Health[(2)]** | **Ecological** | **Human Health** |
| **Pesticides** | | | | |
| Chlordane, alpha | | X | | |
| DDD, total | X | | | |
| DDTs, total | X | | | |
| Endrin | X | | | |
| Heptachlor | X | X | | |
| Heptachlor epoxide | X | | | |
| Lindane | X | | | |
| **PCBs** | | | | |
| PCBs total | X | X | X | |
| **HPAHs** | | | | |
| Benzo(a)anthracene | X | | X | |
| Benzo(a)pyrene | | X | | X |
| Benzo(b)fluoranthene | | X | | X |
| Chrysene | X | | | |
| Fluoranthene | X | | X | |
| Pyrene | X | | | |
| Total HPAHs | X | | X | |
| **Metals** | | | | |
| Chromium | X | | | |
| Copper | X | | | |
| Mercury | X | | | |
| Nickel | X | | | |

*Source: Parsons Engineering Sciences, Inc., 1997.

**Note:**

1. Ecological indicates a contaminant with a significant potential for adverse ecological effects (HQ>10, species affected at different tropic levels or by direct and food web exposure).
2. Human health indicates a contaminant with a potential for human health effects (RME excess $cR>10^{-4}$, CT excess $CR>10^{-4}$, or HQ>1).

### 2.1.2 Source Identification and Evaluation

The general methodology used by Parsons Engineering Sciences, Inc., (1997) for evaluation of pollutant loadings was similar to that of other models used for integrated watershed assessments (e.g., the EPA Office of Water BASINS model), but allowed inclusion of more site-specific and supplemental data. This was required for a comprehensive assessment of toxic pollutant releases into specific areas of Tampa Bay. To compile and analyze point and non-point discharge data, a Geographic Information System (GIS) was developed that included:

- The delineation of drainage basins using stormwater atlas sheets and topographic maps
- A pollutant loading model developed using land use/soil characteristics and stormwater characterization data
- Point sources identified using state/federal water quality monitoring databases and state/local agency permit application/monitoring files
- Atmospheric loading estimates based on previously measures deposition rates
- Historical releases of contaminants identified using databases and permit files

Sediment contaminants identified as COCs for Hillsborough Bay based on a significant potential for adverse ecological or human health effects included: four metals (chromium, copper, mercury, and nickel); HPAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, pyrene, and total HPAHs); five chlorinated pesticides (chlordane, DDT/DDD, endrin, heptachlor/heptachlor epoxide, and lindane); and total PCBs.

Sediment contaminants identified as COCs for Boca Ciega Bay based on a significant potential for adverse ecological or human health effects included: HPAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, fluoranthene; total HPAHs); and total PCBs.

Source identification is a non-trivial problem. For example, practical field experience during NPDES efforts for FDOT has indicated that available listings and mappings of industries by SIC code are generally of limited accuracy and are not up-to-date (about 50 percent correctly identify active operations). While sediment contaminants may be correlated with certain businesses and industries as likely sources, locating the actual source may require intensive field investigation.

Therefore, one of the first tasks of this project was to meet with various municipalities within each sub-basin and other regulatory agencies to generate information on compliance and information for various source facilities identified for specific COCs. Table 2 lists the contacts made from various municipalities, agencies and their respective staff who were met or contacted.

A key element to be determined during the development of the Sediment Contaminant Loading Action Plan is whether sources for the identified existing high levels of contaminants are continuing to generate the contaminants. It is possible that some of the sources no longer exist as industries have changed locations or closed or that pollutant discharges have already been significantly reduced as a result of newly required regulatory controls.

Concurrently, a field reconnaissance was conducted to verify the location of various point sources identified in the Parson Engineering Science, Inc. (1997) report. Table 3 lists all facilities identified in federal (UFSEPA), state (FDEP), and local (county) databases for permitted discharges, including handling of COCs, Comprehensive Environmental Response Compensation and Recovery Act, (CERCLIS facilities).

While conducting field source verification, an attempt was made to inspect each facility that was located in each sub-basin as well as interview appropriate personnel at each facility. Photographs were taken when possible to document site conditions. The field reconnaissance efforts in Delaney Creek revealed that several of the point sources identified as sources of COCs were either present, but no longer in operation, physically no longer present, or incorrectly identified in this sub-basin. However, for Long Bayou all the facilities reported in the previous study were identified in that sub-basin.

**Table 2**
**List of Contacts**

| Agency/Co. | Contact Name | Phone Number |
|---|---|---|
| **DELANEY CREEK SUB-BASIN** | | |
| Hillsborough Co. | Eli Araj | (813) 272-5912 |
| Hillsborough Co. | Dan Putnam | (813) 272-5912 |
| City of Tampa | Mike Burwell | (813) 274-7864 |
| EPC – Hillsborough | Steve Grabe | (813) 272-5960 |
| EPC – Hillsborough | Tom Cardinale | (813) 272-5960 |
| EPC – Hillsborough | Chuck Heintz | (813) 272-5788 |
| Hillsborough Co. | Rhonda L. Townsend, P.E. | (813) 272-5912 |
| Tampa Port Authority | David A. Parsche' | (813) 272-0513 |
| **LONG BAYOU SUB-BASIN** | | |
| Pinellas Co. | Don Moores | (813) 464-4761 |
| Pinellas Co. | Andy Squires | (813) 464-4425 |
| Pinellas Co. | Bob Peacock | (813) 464-7565 |
| City of Clearwater | Terry Finch | (813) 562-4742 |
| St. Petersburg | Mike Link | (813) 893-7845 |
| City of Pinellas Park | Robert G. Bray, Jr. AICP | (813) 541-0704 |
| City of Pinellas Park | Jeffrey F. Sabiel | (813) 541-0772 |
| City of Largo | Kevin J. Becotte, P.E. | (813) 587-6713 |
| **AGENCIES** | | |
| SWFWMD – SWMM | Scott Stevens | (813) 985-7481 |
| SWFWMD – SWMM | Mike Holtkamp | (813) 985-7481 |
| SWFWMD – SWMM | Joanne Macrina | (813) 985-7481 |
| FDOT | Carlos Lopez | (813) 975-6162 |
| FDEP | Eric Livingston | (850) 921-9915 |
| FDEP | Kathy Lyle | (813) 744-6100 |
| FDEP | Randy Cooper | (813) 744-6100 |
| FDEP | Kim Ford | (813) 744-6100 |
| FDEP | Stormy Ingold | (813) 744-6100 |

**Table 3**
**Permitted Facilities in Delaney Creek and Long Bayou Sub-basins***

| Delaney Creek | |
|---|---|
| **Reported Facility Name** | **Facility Location** |
| TECO-Gannon | Delaney Creek |
| Chloride Automotive Batteries | Delaney Creek |
| Bay Drum | McKay Bay |
| A-AAA Printing Link Co. | Delaney Creek |
| MRI Corp | Delaney Creek |
| Florida Steel Corp Tampa Mill Division | Delaney Creek |
| Reeves Southcaslin | Tampa Bypass Canal/Palm River |
| Peak Oil Co/Bay Drum Co | Delaney Creek |
| Orient Park | Palm River |
| Royal Chrome Bumper | Palm River |
| Stauffer Chemicals/Tampa | Palm River |
| Hordis Brothers | Delaney Creek |
| FMC Corp. | Palm River/Ditch |
| Raleigh Street Dump Site | Delaney Creek |
| **Long Bayou** | |
| Ewell Industries Inc. | Long Bayou |
| St. Petersburg-Northwest-WWTP | Long Bayou |
| USDOE Pinellas Plant | Long Bayou |

*Source: Parsons Engineering Sciences, Inc., 1997, EPA and FDEP Point Source Permit Compliance Database Query.

### 2.1.3 Prioritization of Sub-basins

Sub-basins within the upper Hillsborough and Boca Ciega Bays drainage basins were ranked based on total loading (point and non-point discharges) from sources within each basin. Sub-basins were ranked using the following parameters:

- Total loading of COCs without Oil and Grease
- Total loadings for classes of COCs (i.e., metals, PAHs, pesticides, and PCBs).
- Sum of ranks for total loadings and classes of COCs
- Total loading of Oil and Grease
- Total loading of COCs including Oil and Grease

Table 4 shows the ranking (Parsons Engineering Sciences, Inc. 1977) of various sub-basins within Hillsborough and Boca Ciega Bays.

**Table 4**

**Sub-basin Ranking Based on Estimated Loading of COCs***

| Hillsborough Bay | | Boca Ciega Bay | |
|---|---|---|---|
| **Sub-basin** | **Rank** | **Sub-basin** | **Rank** |
| Delaney Creek | 1 | Long Bayou | 1 |
| Lower Hills. River No. 1 | 2 | Direct Runoff to Bay | 2 |
| Lower Hills. River No.2 | 3 | St. Joe's Creek | 3 |
| Ybor Channel | 4 | Cross Canal | 4 |
| Tampa Bypass Canal | 5 | Lake Seminole | 5 |
| McKay Bay No. 1 | 6 | Pinellas Park | 6 |
| Curiosity Creek | 7 | Direct Runoff to Bay | 7 |
| Direct Runoff to Bay | 8 | Direct Runoff to Bay | 8 |
| Mango Drain | 9 | Direct Runoff to Bay | 9 |
| Palm River | 10 | Direct Runoff to Bay | 10 |
| Davis Islands | 11 | Direct Runoff to Bay | 11 |
| Black Point | 12 | Clam Bayou Drain | 12 |
| Bellows Lake Outfall | 13 | Bear Creek | 13 |
| McKay Bay No. 2 | 14 | Direct Runoff to Bay | 14 |
| Ditch | 15 | Direct Runoff to Bay | 15 |

*Ranking as indicated by Parsons Engineering Sciences, Inc., (1997), using spreadsheet based pollutant load model.

### 2.1.4 Priority Sub-basin Identification

The Delaney Creek sub-basin (Figure 1) is approximately 11,960 acres, which extends east-west from Township 29 South and 30 South to Range 19 East and 20 East. The sub-basin encompasses the city of Palm River, Limona and Brandon. The Long Bayou sub-basin (Figure 2) is approximately 4,700 acres, which runs north-south from SR 64 in the City of Largo to SR 690 in the City of St. Petersburg. Tables 5 and 6 show the land uses for the two sub-basins as obtained from the Southwest Florida Water Management District's (SWFWMD), Geographic Information Systems (GIS) database (1990). Figures 3 and 4 are graphic representations of the land use obtained from the SWFWMD GIS database (1990).

In our meeting with Pinellas County staff it was noted that the Long Bayou sub-basin boundary as identified by Pinellas County was different than that obtained from SWFWMD's GIS database. However, both sub-basin boundaries in the Parsons Engineering Sciences, Inc., (1997) report were verified by obtaining information from SWFWMD. For this project, the sub-basin boundary information obtained from SWFWMD for Long Bayou will be used to maintain consistency with the previous studies.

**Table 5**
**Long Bayou Drainage Basin Land Use Summary**

| FLUCS Code Level 1 | Area in Acres | Percentage of Basin |
|---|---|---|
| 1-Urban and Built Up | 1,086 | 23.11% |
| 2-Agriculture | 131 | 2.79% |
| 3-Rangeland | 24 | 0.52% |
| 4-Upland Forests | 479 | 10.19% |
| 5-Water | 1,777 | 37.81% |
| 6-Wetlands | 591 | 12.58% |
| 7-Barren Land | 51 | 1.09% |
| 8-Transportation, Communication & Utilities | 548 | 11.66% |
| 9-Special Classifications | 12 | 0.25% |
| **Total** | **4,699** | **100%** |

**Table 6**
**Delaney Creek Drainage Basin Land Use Summary**

| FLUCS Code Level 1 | Area in Acres | Percentage of Basin |
|---|---|---|
| 1-Urban and Built Up | 7,631 | 63.36% |
| 2-Agriculture | 1,624 | 13.75% |
| 3-Rangeland | 322 | 2.72% |
| 4-Upland Forests | 842 | 7.13% |
| 5-Water | 290 | 2.46% |
| 6-Wetlands | 462 | 3.91% |
| 7-Barren Land | 48 | 0.41% |
| 8-Transportation, Communication & Utilities | 739 | 6.26% |
| **Total** | **11,958** | **100%** |

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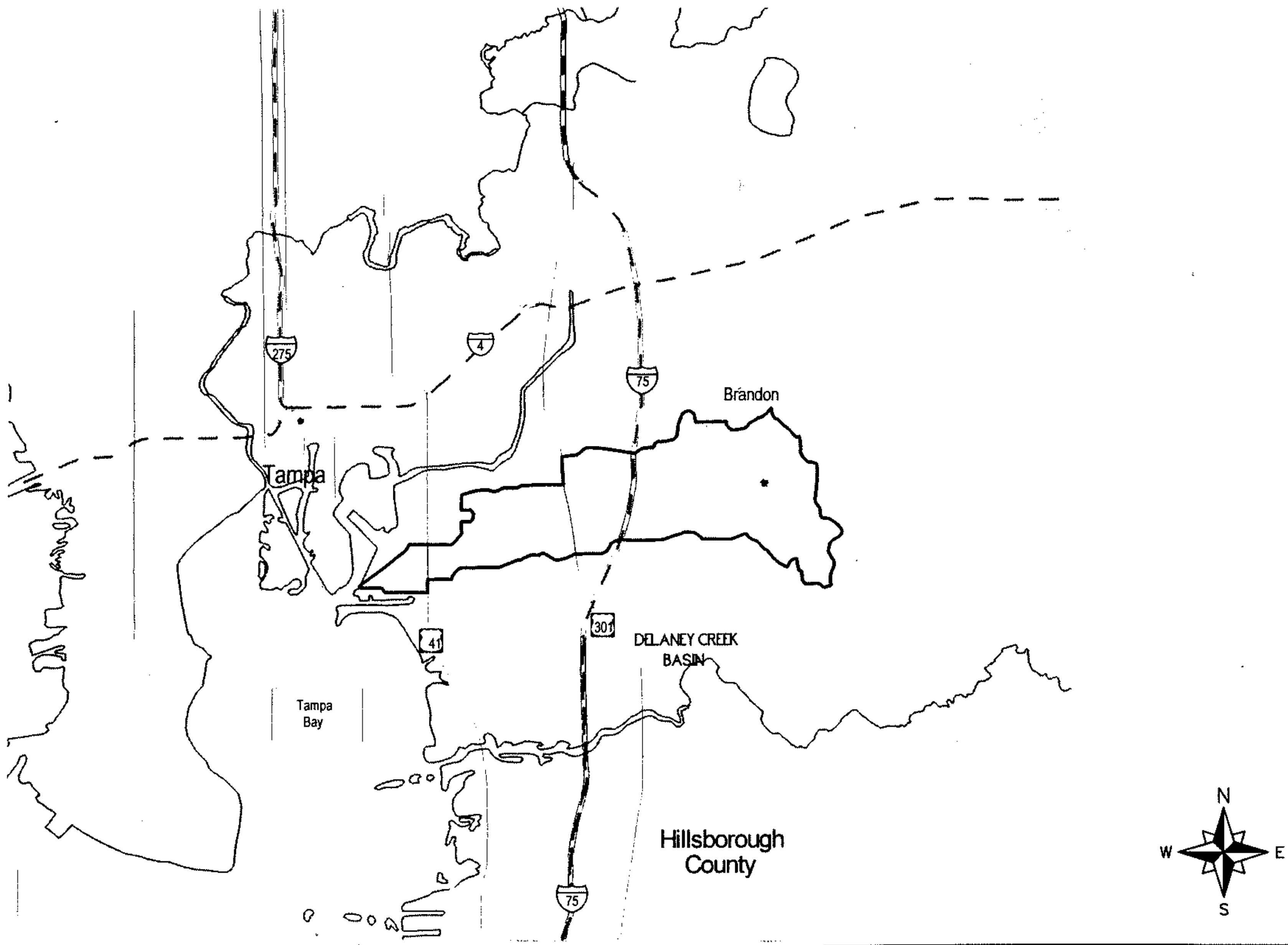


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| REVISED: | |
| DRAWN BY: | L.E.Y. |
| SCALE: | NOT TO SCALE |
| PROJECT NO.: | 969566 |

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**Tampa Bay Natioal Estuary Program**

**FIGURE 1**
**DELANEY CREEK**
**SUB-BASIN**

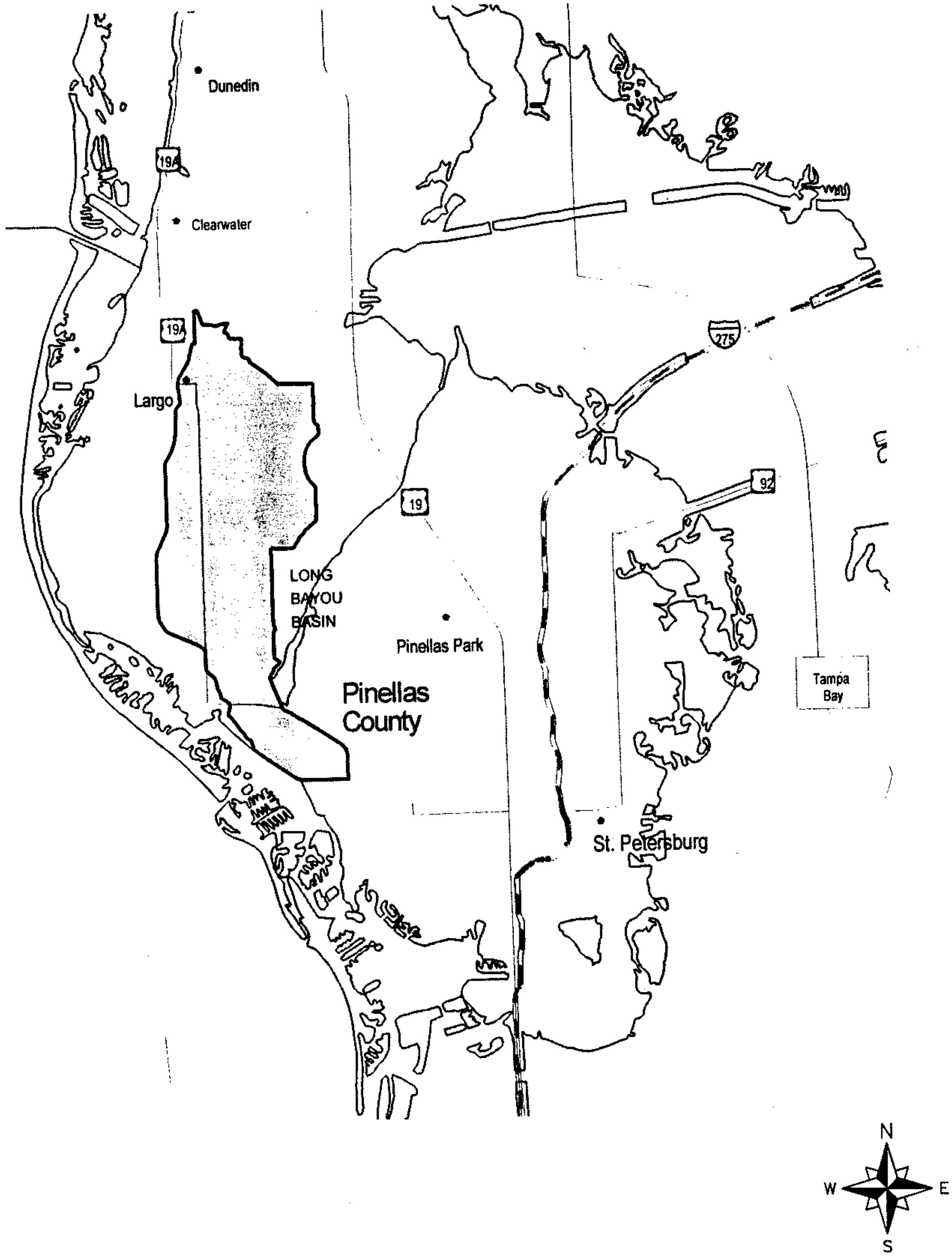




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**FIGURE 2**
**LONG BAYOU**
**SUB-BASIN**

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PLOT DATE: 3-22-99

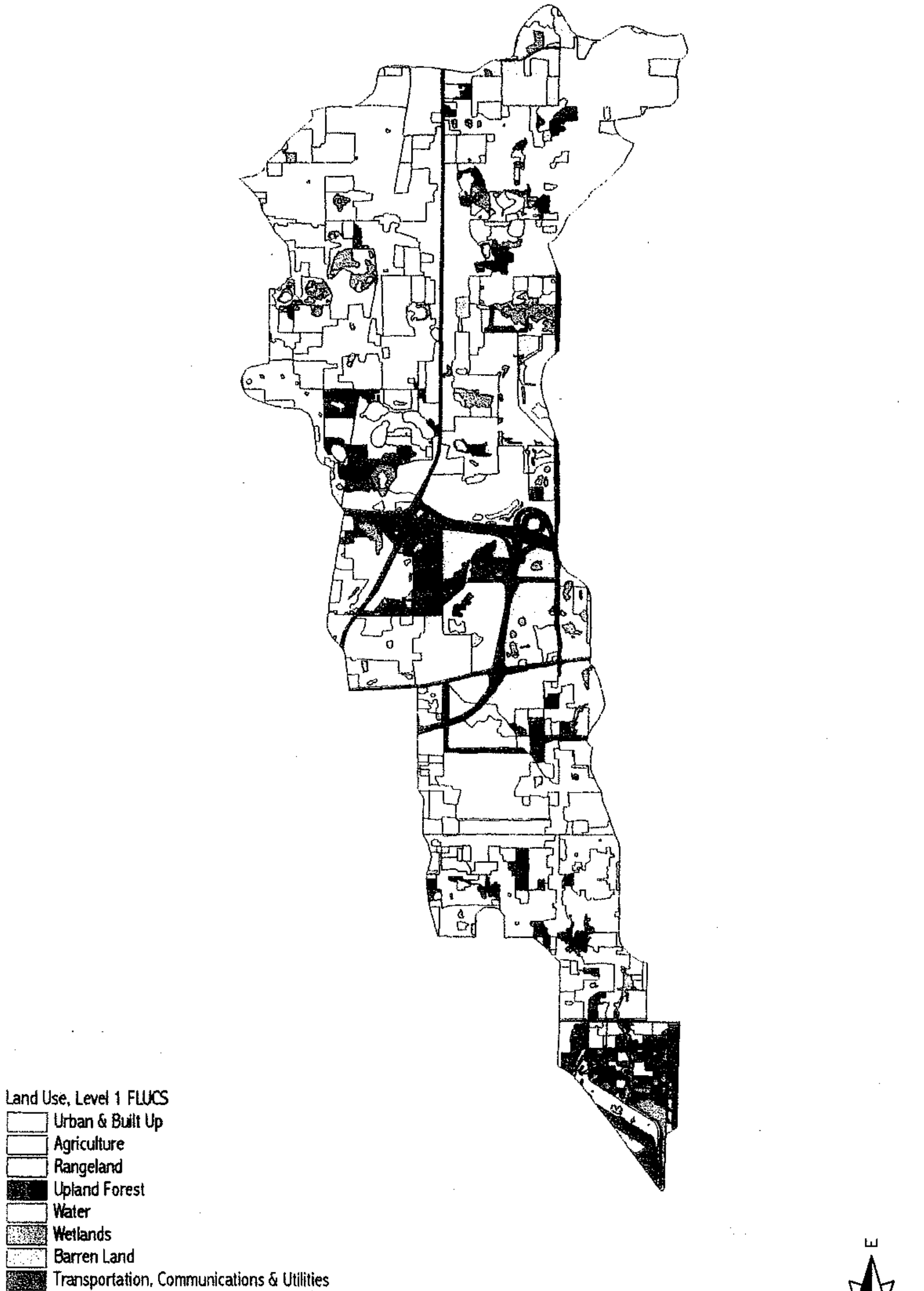


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**FIGURE 3**
**DELANY CREEK SUB-BASIN**
**LAND USE, 1990**

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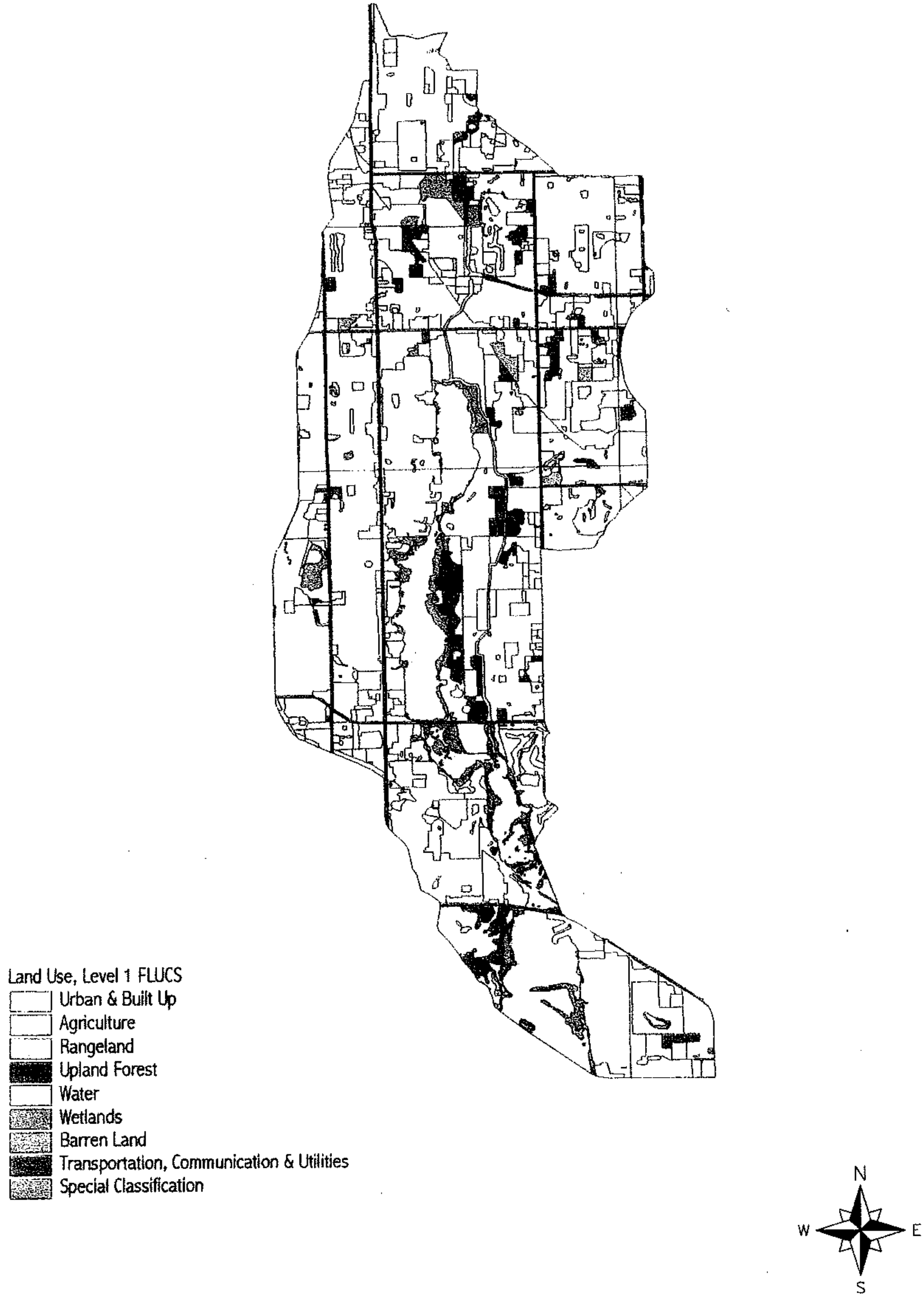


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**FIGURE 4**
**LONG BAYOU SUB-BASIN**
**LAND USE, 1990**

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## 2.2 Sediment Contamination in Sub-Basins

### 2.2.1 Delaney Creek Sediment Contamination

Contaminated sediments have been identified in Delaney Creek over a one-mile reach in the vicinity of US 41. Industrial land uses adjacent to or near the creek in this area include Tampa Bay Fiberglass, Hillsborough Resource Recovery Corporation (HRRC), the site formerly known as the Chloride Metals site (now GNB, after its newest owner), a battery casing landfill, Tampa Tank and Welding, the Raleigh Street Dump, an automobile scrap yard, and the Nitram, Inc. fertilizer facility. The GNB facility produced batteries from 1943 to 1988, when the smelting plant was closed. Fabrication of lead roof flashing and x-ray shielding from lead sheeting occurred at the site at least until August 1998 (Black & Veatch, 1998). The GNB site is now a superfund site and the subject of an enforcement action from the FDEP. Other industrial sites adjoining the GNB site include the Carroll Tire Company and Tampa Tanks.

A smelter was operated at the GNB site to recycle lead and manufacture batteries. Automobile, golf cart, and industrial batteries were recycled at the site. Slag, battery casings, and other waste material have been disposed near the facility and adjacent to and in Delaney Creek over the years (RMT, 1996a). The following information has been obtained from the FDEP files of the enforcement cases against GNB, unless specifically stated.

#### 2.2.1.1 Evidence of Contamination

Soil and ground water from upland areas and sediments in Delaney Creek were sampled for dissolved and total metals, arsenic, Volatile Organic Compounds (VOCs), and other contaminants (CH2M Hill, 1993). Arsenic, antimony, and VOCs were found in soil and ground water on lands nearby the creek channel. Lead and VOCs were the only contaminants found in sediments at elevated levels. Lead was found in very high levels on a wide-spread basis, and is the focus of the currently on-going cleanup at the site, as described below.

1) <u>Lead</u>

Sediment testing in 1980 and 1981 by Seaburn and Robertson found elevated lead concentrations in Delaney Creek sediments. Subsequent testing by CH2M HILL (1993, 1994) in 1991 and 1993 also found elevated (above FDEP standards) lead levels, but at concentrations lower than 1980 levels. Additionally, concentrations were found to be higher in deeper sediments (1-2 feet below surface) in the creek (RMT, 1996b and 1997), suggesting that maximum deposition rates occurred as a result of past activities. Standards (probable effects level, or PEL, of 112 mg/kg) for lead were exceeded for 1991 sampling results at one site with lead concentrations of 295 mg/kg in the 0-1 foot depth ranges, and 776 mg/kg in the 1-2 foot depth range. 1993 sampling results showed two locations with exceedances, one with lead concentrations of 208 mg/kg in the 0-1 foot depth range and one with 234 mg/kg in the 1-2 foot depth range (CH2M HILL, 1993). Organic and muck sediments contained three to five times as much lead as sandy sediments. Background (upstream) sediment lead levels ranged from 2 to 5 mg/kg.

Further testing in 1993 revealed that antimony and arsenic levels in creek sediments were minimal (CH2M HILL, 1993), although supplemental sediment testing (RMT, 1997) found antimony levels above the PEL at one site in Delaney Creek, at US 41. Additionally, surface water testing in 1991 showed that lead concentrations did not meet standards at four of five sites (range 10 to 33 mg/L).

Elevated lead levels were also found in on-site and off-site ditches and a retention pond at the GNB site. The GNB site Contamination Assessment Report (CAR) (CH2M HILL, 1993), recommends annual sampling of Delaney Creek sediments to verify the trend in decreasing sediment lead concentrations.

Supplemental sediment sampling (RMT, 1997) found lead at levels exceeding the PEL at 11 of 15 sites in Delaney Creek within 1000 feet of the GNB site. Concentrations were highest at all but one of the 11 contaminated sites in the 1-2 foot depth range. Four of the sites had lead concentrations over 1000 mg/kg. The antimony concentration at one sampling site adjacent to the GNB site (20 mg/kg) also exceeded the PEL of 12 mg/kg.

A site inspection of the privately owned HRRC site, a construction and demolition debris dump and transfer site just downstream of the GNB site, found elevated levels of metal, polynuclear aromatic hydrocarbons (PAH), and pesticides in on-site soil samples, but not in ground water (Black & Veatch, 1998). Sediment sampling in 1997 revealed elevated levels only of lead in Delaney Creek (range 200 to 360 mg/kg) adjacent to the HRRC site.

Sediment sampling and Toxicity Characteristic Leaching Procedure (TCLP) testing completed for Hillsborough County (Professional Service Industries, 1992) found lead concentrations above the PEL at six of 15 sites in Delaney Creek between Tampa Bay Fiberglass and Nitram, Inc., in the reach of the GNB site. Five of the six exceedances were at sites adjacent to or just downstream of the GNB and HRRC sites. However, none of the TCLP results exceeded the USEPA Maximum Contaminant Levels (MCLs).

Finally, in 1997 the FDEP completed an assessment of potential impacts to water and sediment quality resulting from discharges from the Nitram, Inc. fertilizer facility upstream of the GNB site. Results of metals testing from sediments at five sites along Delaney Creek showed the only PEL exceedance to be for lead, at the US 41 sampling location adjacent to the GNB site. However, mercury levels were elevated in effluent discharged from the Nitram site.

2) Volatile Organic Compounds

Elevated levels of VOCs have been identified in Delaney Creek sediments at US 41 (FDEP, 1994). The VOC plume in ground water at the GNB site appeared to originate from on-site septic tanks (FDEP, 1995). One of the buildings at the GNB site had been used for vehicle painting and equipment maintenance, which are common sources of VOCs.

**Conclusions**

Based on the results of ground water, surface water, soil, and sediment testing summarized above, it is likely that the observed elevated concentrations of lead found in Delaney Creek sediments resulted from past activities at industrial sites along the creek. This conclusion is based on the following evidence:

- A lead smelter operated at the GNB site from 1943 to 1988. The smelter had a direct surface water discharge to Delaney Creek. Batteries were recycled, and battery casings, electrolyte fluid, slag, and other waste materials were disposed near the creek. Stormwater from waste disposal areas flow to ditches and Delaney Creek.
- The smelter at the GNB site has not operated since 1988, although the fabrication of lead products occurred at the site until a few years ago.
- No likely source of lead loading has been identified upstream of the GNB site.
- Lead concentrations in sediments are still above PEL levels, but appear to have decreased during the past 15 years.
- Lead concentrations are generally higher in sediments one to two feet below the sediment surface, suggesting that maximum rates of lead loading occurred in the past.
- The highest lead concentrations in Delaney Creek sediments have been observed near the US 41 bridge adjacent to an on-site GNB ditch. However, stormwater runoff from US 41 could also contribute to elevated lead concentrations at this site.
- Sediment contamination has been characterized as so severe that disturbing sediments may endanger living resources in Delaney Creek and Hillsborough Bay (FDEP, 1995; RMT, 1998). Because sediments with lower lead concentrations appear to be covering the more contaminated sediments, it was suggested that the creek sediments may best remain *in situ*. However, further study is needed to characterize local and downstream benthic communities, and to evaluate the risk of possible adverse impacts if sediments are disturbed.

As stated above, the GNB site is currently the subject of an FDEP enforcement action. Final plans for site remediation and creek sediment dredging are being negotiated due to the high levels of contamination at the site along Delaney Creek The shoreline area will be hydraulically isolated with a slurry wall, and the site will be fenced for no access after soil and ground water cleanup has been completed. No opportunities for using the site for stormwater treatment have been acknowledged at this time.

### 2.2.2 Long Bayou Sediment Contamination

The other priority basin, the Long Bayou basin in Pinellas County, was suspected of being subject to elevated levels of contaminants originating from the surrounding urban land uses. However, interviews with state, local, and federal officials failed to reveal any sediment testing that had been completed in this water body. Testing in Boca Ciega Bay, west of Long Bayou, however, has been completed through a National Oceanic Atmospheric Administration (NOAA) sampling program (Long et al., 1995). Testing in northern Boca Ciega Bay showed elevated levels of several contaminants as described in Zarbock et al. (1997).

Additionally, an attempt was made to identify public projects that may serve to reduce contaminant loadings to the bay. For example, regional stormwater ponds could be enhanced to maximize their effectiveness in contaminant removal. However, interviews with local government officials failed to provide any potential projects of this nature.

In 1997 a Lake Seminole Sediment Characterization Study was completed by BCI/PBS&J for Pinellas County. Lake Seminole, encompassing some 684 acres, is the second largest lake located in Pinellas County, Florida. It is a freshwater water body consisting of two large lobes on a north-south axis connected by a narrow channel. The lake's entire watershed (3,480 acres) and shoreline are highly developed with old and new commercial and residential development, with the exception of the county-owned Lake Seminole Park, located on the southeast shore of the lake. The land use in the watershed is comprised of residential, commercial, office space, and open space.

In the past years, state and local agencies and Pinellas County have received complaints about Lake Seminole's water quality. Therefore, the Pinellas County Board of County Commissioners initiated development of a long-term management plan to improve water quality with the cooperation o the public, lake users, and state and local agencies with responsibilities on the lake. These agencies included Pinellas County, the Southwest Florida Water Management District (SWFWMD), the Florida Department of Natural Resources, the Florida Department of Environmental Regulation, the Florida Game and Fresh Water Fish Commission, and the Cities of Seminole and Largo.

Previous cooperative watershed assessment work by the SWFWMD and the University of Florida (1991) identified 131 stormwater pipes discharging to the lake or its tributaries, mostly on the west side of the lake. No wastewater treatment facilities were located within the watershed. The trophic state index for the lake was determined to be 74.7 in 1991, placing the lake in eutrophic classification for Florida lakes. This earlier work by the SWFWMD included sediment characterization, which indicated organic surface deposits being confined to near-shore sites with the central locations of both the north and south lobes possessing sandy surface sediments (less than or equal to 2.0 percent organic content). However, isolated pockets of organic surface deposits were found along the north-south axis close to the north shore, in the constriction between the two lobes, and near the southern outflow.

Currently, the lake discharges over a weir structure constructed in the 1940s. The weir is located in the southern lobe of the lake, and water flows into the remnant of what was once the Long Bayou estuary, and ultimately into Boca Ciega Bay.

The overall goal of the study was to determine the possibility of dredging sediments from Lake Seminole and included the results of physical and chemical characterization, lake bathymetry, and volumetric calculations of Lake Seminole sediments.

It was determined that Lake Seminole currently has an estimated total volume of 4.9 million cubic yards (c.y.) of sediments. Of this, 800,000 c.y. is considered to be low density, organic silts, which may need to be removed to improve water quality within the lake. Not included with the 800,000 c.y. is an additional 130,000 c.y. of highly organic, decayed vegetation along the periphery of the lake.

Chemical characterization was performed on Lake Seminole organic silt sediments, water, and elutriate for metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc) and nutrients (total kjeldahl nitrogen, total phosphorus, orthophosphate, nitrate and nitrite combined, sodium and chloride). The sediments were also analyzed for potential for metal toxicity as defined by the Toxicity Characteristic Leaching Procedure (TCLP). The analysis revealed the following:

Sediments

- Sediments do not qualify as hazardous material based on the metal concentrations detected in the TCLP leachate produced.
- All metals, except mercury and thallium, were detected; however, chromium, copper, lead, and zinc were detected at concentrations ranging from about five to 60 mg/kg dry weight.

Water

- Arsenic, chromium, copper, lead, nickel, selenium, silver, and zinc were detected in the lake water; however, only lead and silver concentrations exceeded the Florida Class III freshwater quality standards.
- Soluble parameters demonstrate concentrations of 0.429mg/L for nitrate and nitrite combined and 0.151 mg/L for orthophosphate. Total kjeldahl nitrogen and phosphorus in the water was 3.47 mg/L and 0.346 mg/L, respectively.
- Sodium and chloride were present at approximately 100 mg/L. These two elements are dominant in saline waters and when this value is converted to the standard measure of salinity in part per thousand (ppt), the resulting value of 0.1 ppt is indicative of freshwater.

Although no standards exist for sediment disposal on land, a comparison with Environmental Protection Agency limits for sewage sludge disposal on land shows the sediments are well below the limits and should not pose any land disposal concerns. It should be noted that the sediment analyses indicate a substantial reservoir of nutrients bound to the sediments, and that the purpose of the Lake Seminole restoration project is to remove the internal nutrient source. Metals were the only COCs evaluated. Of these, only Mercury was not detected in either sediment or water. The project is being evaluated for possible options to dredge and remove the organic-bearing sediments to improve the lake's water quality and likely reduce a significant loading of metals to the Bay.

## 2.3 Petroleum Storage Tanks

Contributions of contaminants leaching from the soil is a concern, particularly sources such as underground storage tanks. Contaminants can enter the estuary through infiltration of ground water. Leaching of COCs may be localized, but because of the generally slow movement of ground water, it may take several years for contaminants to reach the estuary. To gain a better insight as to the total number of identified tanks, an inventory was developed based on available data.

### 2.3.1 Underground Storage Tanks Survey

In addition to actual site visits, BCI acquired available data on underground storage tanks in Long Bayou. The data acquisition was limited to only Long Bayou due to budgetary constraints, but similar information for the Delaney Creek sub-basin may be obtained in the future, if needed. Sources of tank data used includes FDEP's Petroleum Contamination Tracking System Report (PCTS) and Stationary Tanks Inventory System List (TANKS). Figure 5 shows the location of all sites identified within Long Bayou. Since absolute precision in facility precedent is not possible, a proximal site area was also conducted which extends 0.1-0.2 miles beyond the Long Bayou boundary.

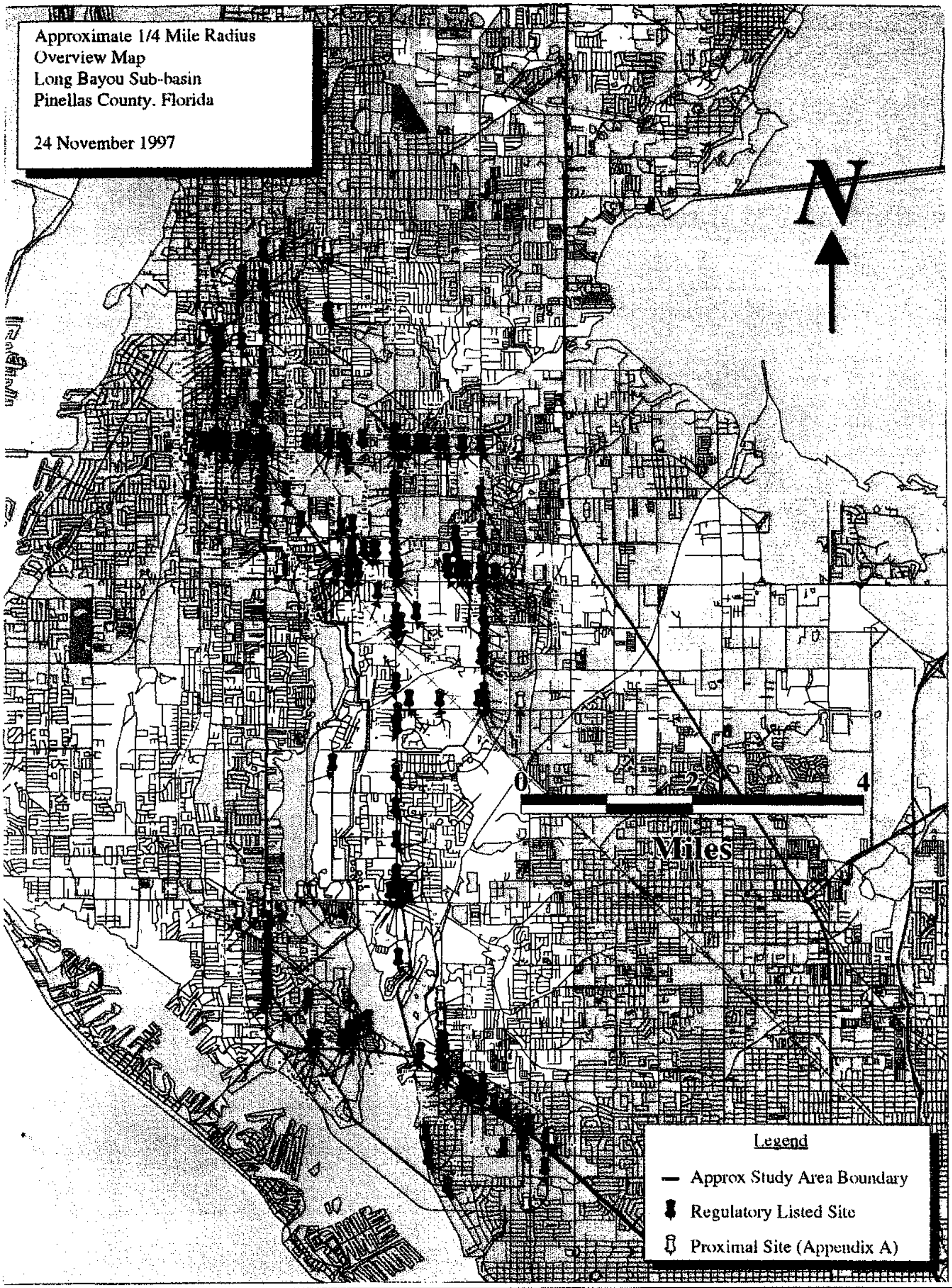


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**FIGURE 5
UNDERGROUND STORAGE TANK SITES IN LONG BAYOU**

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|---|---|---|---|---|

Table 7 is a summary of the sites found in the Long Bayou sub-basin from the PCTS database. Contamination of sites refers to impact to the soil, surface water and/or ground water. In the Long Bayou sub-basin, 52 percent of the facilities have monitoring wells; 41 percent of these facilities are abandoned. We found that 75 percent of the facilities defined by the database search indicate evidence of petroleum contamination. The contaminants identified included generic gases, oils, and unknowns, but did not include COCs.

**Table 7**
**Petroleum Contamination Tracking System**
**Summary of Petroleum Site Conditions**

| Existing Site Condition | Number of Sites | Percent |
|---|---|---|
| Abandoned and Contaminated | 30 | 24 |
| Contaminated with Monitoring Wells | 26 | 21 |
| Abandoned, Contaminated with Monitoring Wells | 22 | 17 |
| Contaminated | 17 | 13 |
| Monitoring Wells Available | 13 | 10 |
| Clean and Operating | 8 | 6 |
| Abandoned | 6 | 5 |
| Abandoned with Monitoring Wells | 5 | 4 |

A poorly monitored but rapidly growing source of contaminants considered was tanks that are only partially buried. Table 8 is a summary from the TANKS database that indicates the percentage of tanks of type above, below, and above/below. There were a total of 251 sites, which have or had under and/or above ground storage tanks. 154 sites no longer have tanks, they have either been removed or concrete filled in place.

**Table 8**
**Summary of Tank Types**

| Type of Tanks | Number of Tanks | Percent |
|---|---|---|
| Underground | 54 | 56 |
| Aboveground | 36 | 37 |
| Above and Underground | 7 | 7 |

The PCTS data query identifies facilities and/or locations that have notified the FDEP of a possible release of contaminants from petroleum storage systems. The mention of a site is an indication that a release has occurred and may pose potential environmental degradation.

It is apparent from this survey alone that storage tanks are a concern. Though monitoring wells and other assessment requirements by regulatory agencies have been valuable, limited funding aid and the high cost of cleanups will very likely preclude cleanup for sometime.

## 2.4 Existing and Proposed Projects In Sub-Basins

As previously stated in Section 4.0, we contacted several municipalities and regulatory agencies to identify any existing or proposed projects in each of the two priority sub-basins. We attempted to identify the type of project, its objectives, a brief description of the project, long-term benefits and, if available, the associated costs. The following is a synopsis of projects that were identified as active or proposed in Delaney Creek and Long Bayou. As stated earlier in the report, the level of proposed project activity within the priority basins is very limited due to land availability and high cost of land purchase. The few projects described were identified based on meetings and telephone conversations with many agency and municipal contacts. However, after these meetings and conversations it was evident that other sub-basins are viewed as being of priority such as St. Joe's Creek, and McKay Bay. These sub-basins are also being evaluated for similar projects in addition to Delaney Creek and Long Bayou.

### 2.4.1 Delaney Creek

#### 2.4.1.1 Delaney Creek Rehabilitation Project

| | |
|---|---|
| Objective: | Reduce Total Nitrogen (TN) and Total Suspended Solids (TSS) loading to Tampa Bay, and the creation of new wetland habitat, but do not specifically address COCs. Construction of this project was completed in 1997. |
| Description: | Routing of base flow, first flush, and minor storm events through an expanded existing wetland system. |
| Watershed Description: | Mostly urbanized watershed with an area of 16 sq. miles. Delaney Creek is one of the most heavily abused creeks in Hillsborough County. |
| Land Use: | Residential, Commercial, some Agricultural. |
| Wetland Acres: | Before: 3.11 acres<br>After: 5.64 acres |
| Project Area: | 10.6 acres |

| | | |
|---|---|---|
| Expected Benefits: | Estimated Current Load (TN): | 4.72 tons/year |
| | Estimated Current Load (TSS) | 40.5 tons/year (BPC: 32.5 lbs/day 59 tons/year) |
| | Treatment Method: | Created Wetland |
| | Treatment Efficiency (TN): | 25% |
| | Treatment Efficiency (TSS): | 75% |
| | TN Load Reduction per year: | 1.18 tons |
| | TSS Load Reduction per year: | 30.38 tons |

| | | |
|---|---|---|
| Project | Site Purchase: | Environmental Lands Acquisition Program (ELAP) |
| | Design & Construction: | Hillsborough County and SWIM |
| | Maintenance & Monitoring: | Hillsborough County |

### 2.4.1.2 Delaney Creek Channel Improvements

Objective:
1) Reduce flooding to homes along Delaney Creek
2) Prevent erosion of creek banks
3) Improve water quality by reducing sediment loading in Delaney Creek which discharges into Tampa Bay. However, the reduction of COCs are not specifically addressed.

Description: Project starts at 86th Street (Hobbs Road) and ends north of the railroad track east of 50th Street (US 41). The distance is 14,582 feet (2.76 miles). The project is anticipated to begin by the year 2001. The cross section of the creek will be increased by reducing bank side slopes to a maximum 3:1 slope. This will increase the flow capacity of the creek while reducing bank erosion. In areas of high erosion, porous articulated concrete block will be used which will allow vegetation to grow and become established in the cell blocks.

Mitigation: There are 6.1 acres of wetland impact for the channel improvements plus an estimated 0.8 acre of impact associated for future bridge replacements at Maydell Drive, 36th Avenue and 70th Street. The project will supply 6.95 acres of "mitigation bench" compensation area classified as PEMI (Palustrine, Emergent, Persistent Vegetation) and 0.05 acre for shrub bank plantings for a total of 7.0 acres.

Dredge & Fill: There are 1.33 acres of fill and 5.57 acres of excavation.

Permits: All permits have been received and implementation is proposed for late 1999.

Project Funding: Hillsborough County. Actual cost not available.

### 2.4.2 Long Bayou

#### 2.4.2.1 Largo Regional Stormwater Treatment Facility Evaluation

Objective: This project will remove pollutants by diverting the flow through a stormwater treatment facility. Non-point source pollution will be chemically treated to significantly reduce total nitrogen and total suspended solids in direct stormwater runoff and base flow. This project, however, does not specifically address the reduction of COCs.

Description: The project site is located in the City of Largo in central Pinellas County. The treatment facility will be constructed on a 76-acre plot of land located immediately south of East Bay Drive opposite Highland Avenue. The treatment facility will handle stormwater from the Main Channel which runs from north to south on the project site and discharges into the Boca Ciega Bay. Stormwater from the Country Club Outfall Canal, located just to the east of the project site, will be diverted onto the site for wetland treatment. The Main Channel and the Country Club Outfall Canal join at the southeastern end of the project site.

The Largo Regional Stormwater Treatment Facility will occupy 24.2 acres of the project site and will utilize aluminum sulfate (alum) injection to treat stormwater for total nitrogen and total suspended solids. Stormwater from the Main Channel will be diverted to the treatment facility and injected with alum. The treated water will then be passed to a 3.2 acre floc settling pond. The accumulated floc will be pumped into the sanitary sewer and the treated water will be allowed to flow into the Country Club Outfall Canal.
Enhancements to the project site will include improvements to 6.7 acres of upland area, 19.85 acres of existing wetlands, and the creation of 0.84 acres

of new wetland. The project also includes water quality monitoring and public education components

Need: Boca Ciega Bay receives stormwater runoff through the Main Channel and the Country Club Outfall Canal from 1,159 highly urbanized acres. The Largo Regional Stormwater Treatment Facility will treat nearly 3000 acre-feet of runoff and base flow from this area.

Benefits: The treatment facility will be capable of removing 3,310 kg/yr of total nitrogen, 767 kg/yr of total nitrogen, 11,700 kg/yr of BOD loadings, 35,926 kg/yr of total suspended solids loadings meeting 94 percent of the TBNEP's 1999 Pollutant Load Reduction Goal. The alum flocs will be pumped to a sanitary sewer thus removing the concerns over aluminum toxicity potentials. Alum treatment has proven to be significantly more cost effective than traditional stormwater BMPs.

Costs: The total cost for design and construction of the facility is estimated at $1,331,547, of which $653,380 (49 percent) is federally funded. The remaining $678,167 is supplied by the City of Largo, SWIM Trust Fund, SWFWMD, and Winn-Dixie donations.

## 2.5 Summary of Findings for Each Sub-Basin

The following points summarize the findings for Delaney Creek:

- COCs include pesticides, PCBs, HPAHs, and metals
- Point source discharges have not been accurately identified
- Principle land uses consist of Urban and Agriculture
- Limited existing project work focusing on water quality improvement, but not directly addressing COCs
- Potential for regional treatment facility – land cost very high
- Major potential industrial pollutant sources exist at the mouth of Delaney Creek
- Existing stormwater management systems appear to be adequately maintained

The following points summarize the findings for Long Bayou:

- COCs include PCBs and HPAHs
- Point source discharges accurately identified
- Principle land uses consist of Urban and Water
- One ongoing "stormwater water quality" project identified, but does not directly address reduction of COCs
- Potential for utilizing end-of-pipe BMPs
- Sediment removal from receiving water bodies a potential water quality benefit
- Existing stormwater management systems appear to be adequately maintained
- Contamination from existing underground storage tanks is a potential concern

# 3.0 OPTIONS FOR CONTAMINANT CONTROL

## 3.1 Global Stormwater Management Practices

### 3.1.1 Stormwater Facilities - Design Operation and Maintenance Considerations

Stormwater runoff is often regarded as the dominant source of pollution to lakes, rivers, bays, and estuaries and is identified as the major source for most of the sediment COCs (Parsons Engineering Sciences, Inc., 1997). Stormwater treatment is often an effective way to reduce the degree of contamination that enters a receiving water body.

Toxic materials and metals enter stormwater ponds either attached to the sediments or in soluble form. Stormwater treatment systems are most efficient at removing suspended sediments. Facilities that include planted littoral shelves and constructed wetlands offer improved removal efficiencies for soluble contaminants. To assure that toxics and metals remain bound to the sediments it is very important that the pond/facility remain aerobic and that the pH remain around neutral. In the case of infiltration systems, organic rich soils tend to improve the removal efficiency of toxic materials and metals by fostering attachment to soil particles.

Stormwater treatment systems are unique in that they have the capability to not only treat stormwater runoff, but also, atmospheric deposition that occurs within the basin, as well as illicit discharges that report to stormwater drainage systems. Stormwater treatment systems also have the ability to provide many side benefits in addition to water quality improvement such as public education opportunities, flood attenuation, and wildlife habitat.

Stormwater treatment facilities that are neglected and improperly maintained can effect immediate and severe problems both in the near site area as well as the receiving water body. Impacts include aesthetics, odors, mosquitoes, rodents, disease, discharge water quality impairment and subsequent degraded water quality and environmental damage to receiving water bodies.

Stormwater treatment mechanisms occur in a wide variety of configurations and types. Treatment can occur in the form of structural or non-structural controls. Appendix A has a listing and brief description of some of the popular structural and non-structural control techniques. The appendix also contains additional information on BMPs from the TBNEP technical publication No. 07-96, Watershed Management Model for Optimal Allocation of Best Management Practices (1997). Tables 7 through 10 summarize the pollution reduction efficiencies of structural BMPs and source control techniques for various parameters.

## Table 9
## Average Percent Pollution Reduction Estimates for Select Structural Control Techniques Based on Actual Monitoring Data **

| | Pollutant Constituent | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Ortho | Soluble | Total | Nitrate | Nitrite | Kjeldahl | Ammonia | | | | | | Fecal Coliform |
| | TSS | p | p | p | TN | NO2 | NO3 | TKN | NH4 | BOD | COD | Pb | Zn | Cu | |
| Extended Dry Detention | 54 | 29 | N/D | -6 | 31 | N/D | 18 | 30 | 54 | 52 | 20 | 52 | 25 | 31 | 69 |
| Wet Detention | 65 | 50 | 78 | 56 | 33 | 70 | 49 | 29 | 43 | 40 | 42 | 71 | 54 | 66 | 58 |
| Extended Wet Detention | 77 | 65 | N/D | N/D | 54 | N/D | N/D | N/D | N/D | 36 | N/D | 39 | 21 | N/D | 84 |
| Stormwater Wetlands (created) | 69 | 42 | N/D | 46 | 24 | N/D | 52 | 19 | 55 | 20 | 33 | 74 | 47 | N/D | 58 |
| Extended Detention Wetland | 57 | 23 | N/D | 17 | 21 | N/D | 30 | 19 | N/D | N/D | N/D | 61 | -73 | N/D | N/D |
| Natural Wetlands | 91 | 62 | 93 | -109 | 43 | 90 | 80 | 70 | 80 | 80 | N/D | 81 | 74 | 60 | N/D |
| Pond/Wetland Systems | 76 | 55 | N/D | 11 | 37 | N/D | 28 | 5 | -1 | 42 | 61 | 55 | 63 | N/D | N/D |
| Infiltration Systems - Basins and Trenches | 90 | 65 | N/D | N/D | 61 | 10 | N/D | N/D | N/D | 85 | 87 | 90 | 87 | N/D | 94 |
| Stormwater Filters sand or peat/sand | 85 | 70 | N/D | 40 | 43 | N/D | N/D | N/D | N/D | 90 | N/D | 60 | 60 | 60 | N/D |
| Porous Pavement | 81 | 63 | N/D | N/D | 80 | N/D | N/D | N/D | N/D | N/D | 82 | 98 | 98 | 98 | N/D |
| Swales | 83 | 63 | 61 | N/D | 39 | 35 | N/D | 63 | N/D | 11 | N/D | 72 | 76 | 56 | N/D |
| Water Quality Inlets - Skimmers and Trash Screens | 15 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Off-Line Retention | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| On-Line Retention | 67 | 58 | N/D | N/D | N/D | N/D | N/D | 34 | N/D | 65 | N/D | 74 | N/D | N/D | N/D |
| Overland Flow – Grass | 30 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | 19 | N/D | N/D | N/D | 50 |
| Overland Flow – Grass/soil | 99 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D | 88 | N/D | N/D | N/D | 98 |

** Refer to list of references

N/D indicates No Data available

## Table 10
## Estimated Percent Pollution Reduction Ranges for Structural BMP Control Techniques **

| | Pollutant Constituent | | | | | | |
|---|---|---|---|---|---|---|---|
| Stormwater Best Management Practice Structural Control Method | Total Suspended Solids | Nutrients | | Oxygen Demanding | Trace Metals | Bacteria | Overall Efficiency |
| | | Phosphorus | Nitrogen | | | | |
| Extended Dry Detention Pond | 3 | 5 | 4-5 | 3-4 | 3-4 | 2-3 | Moderate to Low |
| Wet Detention | 1-2 | 2 | 3 | 3 | 2 | 3 | Moderate to High |
| Extended Wet Detention Pond | 2 | 3 | 3 | 4 | 4 | 2 | Moderate |
| Stormwater Wetlands (created) | 2 | 3 | 3-4 | 4 | 2-3 | 3-4 | Moderate |
| Extended Detention Wetland | 2 | 4-5 | 4 | 6 | 6 | 6 | Moderate to Low |
| Natural Wetlands | 1 | 1-4 | 2 | 1-2 | 2 | 6 | Moderate to High |
| Pond/Wetland Systems | 2 | 3-4 | 4-5 | 3 | 3 | 6 | Moderate |
| Infiltration Systems - Basins and Trenches | 1 | 2-3 | 3-4 | 2 | 1-2 | 1-2 | Moderate to High |
| Filters- sand or peat/sand | 1-2 | 3 | 3-4 | 1-2 | 2-3 | 6 | Moderate |
| Porous Pavement | 1-2 | 2-3 | 2 | 2 | 1 | 2 | Moderate |
| Swales | 2 | 3-4 | 4 | 5 | 2-3 | 6 | Moderate to Low |
| Water Quality Inlets - Skimmers and Trash Screens | 5 | 6 | 6 | 6 | 6 | 6 | Low |
| Off-Line Retention | 1 | 1 | 1 | 1 | 1 | 1 | High |
| On-Line Retention | 2 | 3 | 4 | 2-3 | 2 | 6 | Moderate |
| Overland Flow - Grass/soil | 1 | 6 | 6 | 2 | 6 | 1 | Moderate to High |

| | |
|---|---|
| 1 | 80 to 100% removal efficiency |
| 2 | 60 to 80% removal efficiency |
| 3 | 40 to 60% removal efficiency |
| 4 | 20 to 40% removal efficiency |
| 5 | 0 to 20% removal efficiency |
| 6 | Insufficient data available |

** Refer to list of references

## Table 11
## Summary of Characteristics, Limitations, and Requirements for Stormwater Best Management Practices **

| | Characteristic | | | | | | |
|---|---|---|---|---|---|---|---|
| Stormwater Best Management Practice Control Method | Area Requirement (acres) | Soil Infiltration Req'ment | High Water table Limitations | Sediment Load Limitations | Relative Space Consumption | Maintenance Frequency | Construction Cost |
| Extended Dry Detention Pond | >10 | None | Probable | possible | high | moderate | low |
| Wet Detention | >10 | None | None | possible | mod. to high | moderate | mod. to high |
| Sediment Sump | none | None | None | none | moderate | mod. to high | low |
| Extended Wet Detention Pond | >10 | None | None | possible | mod. to high | moderate | mod. to high |
| Stormwater Wetlands (created) | >2 | None | None | possible | mod. to high | high initially | high |
| Extended Detention Wetland | >10 | None | None | possible | mod. to high | high initially | high |
| Natural Wetlands | none | None | None | possible | low | moderate | low |
| Pond/Wetland Systems | >10 | None | None | possible | mod. to high | moderate | high |
| Infiltration Systems: | | | | | | | |
| Trenches | <10 | Rapid | Probable | definitely | mod. to high | mod. to high | low to med. |
| Basins | <25 | Rapid | Probable | definitely | high | moderate | low |
| Stormwater Filters- Sand or sand/peat | <5 | Rapid | Probable | definitely | low to mod. | high | moderate |
| Porous Pavement | <10 | Rapid | Definitely | definitely | low | mod. to high | mod. to high |
| Modular Concrete Grid Pavement | <10 | Rapid | Definitely | probable | low | moderate | moderate |
| Grassed Swales | <5 | mod. to rapid | Probable | probable | low to mod. | low | low |
| Water Quality Inlets - | <2 | None | None | probable | low | low | low |
| Skimmers and Trash Screens | | | | | | | |
| Off-Line Retention | <5 | None | Seldom | possible | mod. to high | moderate | mod. to high |
| On-Line Retention | <10 | None | Possible | possible | moderate | moderate | low |
| Overland Flow - Grass/soil | <5 | Rapid | Seldom | probable | low | low | low |

** Refer to list of references

**Table 12**

**Estimated Pollution Reduction Efficiencies of Source Control Techniques ****

| Stormwater Best Management Practice Source Control Method | Pollutant Removal Efficiencies | | | | |
|---|---|---|---|---|---|
| | Suspended Solids | Nutrients | Oxygen Demanding | Metals | Pathogenic Bacteria |
| Street Sweeping | Medium | Low | low | low | low |
| Litter Control Laws | Low to med | low to med | med | low to med | low to med |
| Public Education | Low to med | low to med | low to med | low to med | low to med |
| Traffic Flow Regulation | low | Low | low | med | low |
| Pesticide, Herbicide and Fertilizer Use Control | low | High | med | low | low |
| Review and Enforcement of SWPPP | high | med | med | med | med |
| Improved Maintenance | med | med | med | med | med |
| Illicit Connections Removed | Med to high | med to high | med to high | med to high | med to high |
| Recycling Program | low | Low | low | med | low |

** Refer to list of references

### 3.1.2 Impacts of Stormwater Controls on Ground Water

For many years the engineering community has relied on Stormwater Best Management Practices (BMPs) to control the release of polluted surface water runoff into the state's receiving water systems. Many of the established structural control type BMPs promote the collection of stormwater runoff to an isolated location where the water is allowed to slowly percolate into the underlying soils. This type of BMP is effective for removing pollution loads, which would otherwise have discharged directly to the receiving water body.

A primary concern regarding BMP's that utilize this type of treatment technique is the extent to which the surficial ground water aquifer is impacted. The EPA through the National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Program has requested that municipalities and listed industrial activities address the potential of ground water degradation. Permittees are asked to discuss any known or presumed ground water impacts resulting from the control and treatment of stormwater runoff.

The EPA-supported Nationwide Urban Runoff Program (EPA, December 1993a; EPA, December 1993b; EPA, December 1993c; and EPA, September 1982) conducted extensive investigations on issues of ground water contamination from stormwater ponds by monitoring two sites of varying age and conditions. Following is a brief summary of some of the report findings:

- The majority of pollutants commonly occurring in urban runoff is intercepted during the process of infiltration and is thereby prevented from reaching the underlying saturated zone of the surficial ground water system.
- Pollutants were observed to accumulate in the upper soil layer with concentrations being a function of the time the facility has been in operation.
- The depth of pollutant penetration is a function of the soil type; however, no contaminant constituents were encountered at depths over several meters.
- The ability of the soils to retain the pollutants is unknown; however, the NURP and other studies indicate this as not being a threatening concern.

The United States Geological Survey (USGS) conducted an independent study in 1989, entitled "The Effects of Three-Runoff Detention Methods on the Water Quality of the Surficial

Aquifer System in Central Florida" (USGS, 1989). This report concluded that the water quality variables measured in ground water near the treatment facilities, with very few exceptions, were within drinking water standards. Results of the study indicate that "the natural processes occurring in soils do much to attenuate the constituents prior to reaching the receiving ground water."

Other studies have indicated that the concentration of pollutant constituents are greater beneath stormwater treatment ponds than that in water within the pond itself. These reports also indicate that significant horizontal or vertical migration of these pollutants has not been observed or measured. In a State-wide study, Cox and Livingstone (November, 1997) report that stormwater residues, in most cases, are not hazardous wastes, but precautions should to be taken regardless of the source of the residues.

The municipalities may look to revise locations, frequencies, or methods of how some BMPs are implemented due to findings made during the stormwater management plan process. For example, some entities are looking at modifying their street sweeping locations based on portions of their Municipal Separate Storm Sewer System (MS4) having direct discharge to U.S. waters without pre-treatment provisions within the conveyance system (Personal Communication, FDOT).

Dry weather field screenings of stormwater outfalls is another permit requirement that has forced the municipalities to inspect the MS4 systems for illicit connections. Municipalities are required to inspect outfalls every three years in industrial areas and every five years in other land use areas. If illegal discharges are discovered, the discharges are traced back to their source and the proper agencies notified. This procedure will help to reduce the number of illicit discharges of non-stormwater to the MS4.

The NPDES permits also require the MS4 operators to inspect industries within the catchment area of the MS4 outfalls and ensure that the industries are properly following their Stormwater Pollution Prevention Plan (SWPPP). This permit condition came from the fact that EPA does not have the staff or resources to conduct such inspections and is reliant on local governments to provide such efforts. Thus far, the municipalities in the Tampa Bay area are taking a varied approach to this requirement.

Municipalities with established environmental departments are taking a more involved approach with this permit requirement than are those with fewer staff and limited resources. As such, the industrial business sector is likely seeing a varied amount of government presence relative to the NPDES stormwater management requirements. It is evident however that where the municipality resents itself as a partner to the industry, with the goal of helping the industry to comply with the NPDES regulations, that the greatest level of compliance is likely going to be realized.

### 3.1.3 Operation, Inspection, and Maintenance

As previously emphasized, operation and maintenance of existing stormwater treatment systems is a very effective and economically feasible means of improving and maintaining the quality of surface water that enters Tampa Bay. Over the last five to 10 years state and federal regulation has emphasized the need for municipalities to develop programs specifically aimed at improving stormwater quality. Operation and maintenance driven by a comprehensive inspection program is a major component of a successful stormwater management plan. Inspections of stormwater systems is quite varied and directly dependant on the type of system utilized and the conditions of the site and area served by the facility.

In order to get a better idea of the degree of stormwater treatment that already exists within the subject basins we requested that the SWFWMD provide a listing and map that depicts the number of facilities currently served by a permitted stormwater treatment facility. Additional information obtained included geographic location, type of land use served, and area served. Based on this information it was discovered that approximately 21 percent of the total Delaney Creek basin is currently served by stormwater facilities (70 percent of the developed portion of the basin) (Figure 5). For Long Bayou, 34 percent of the basin is currently served by stormwater facilities (35 percent of the developed basin area) (Figure 6).

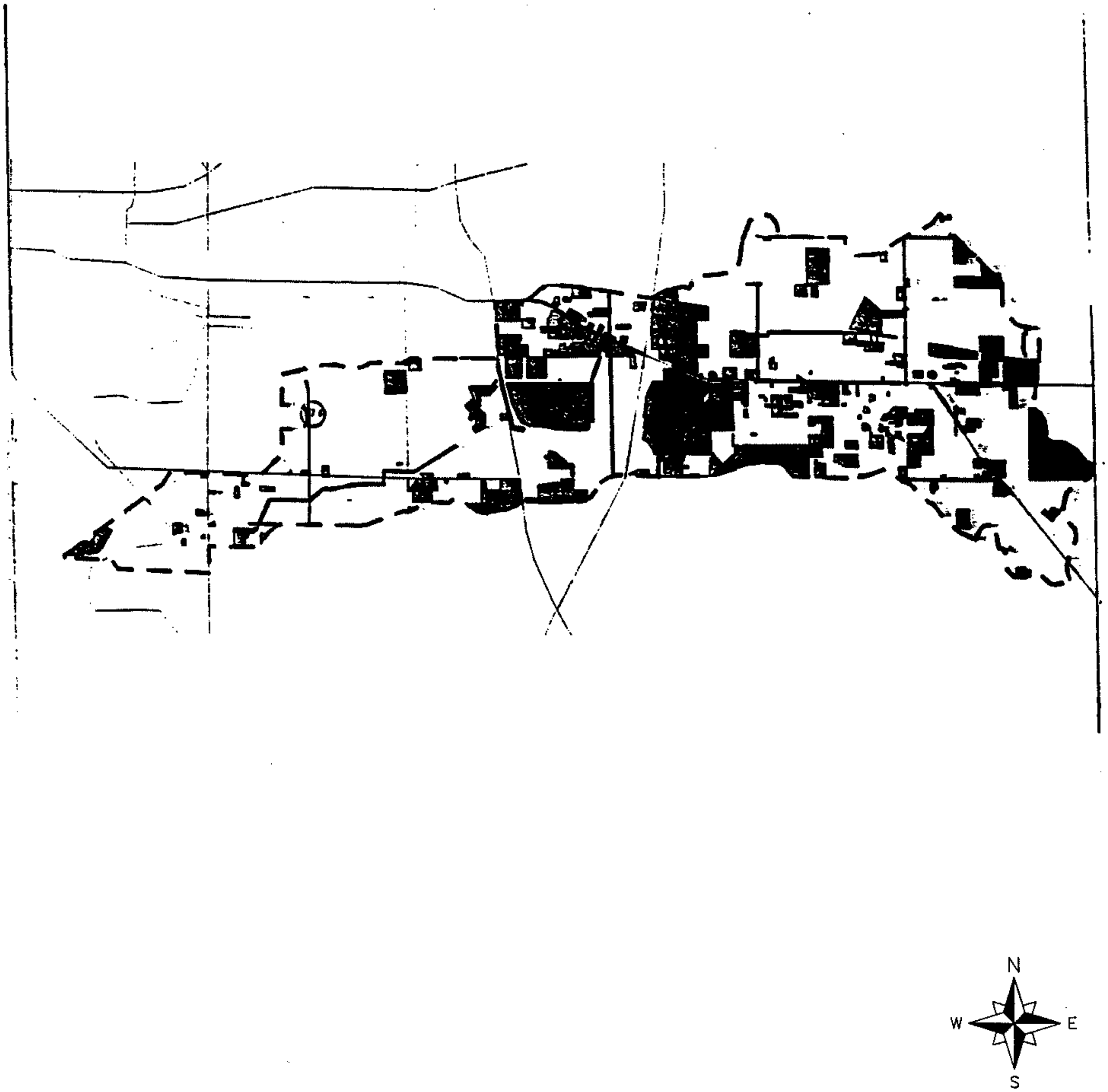
Since 1990 the SWFWMD regulation has required recertification of all new stormwater treatment systems on a 24-month cycle (minimum). As part of the recertification program the systems are visually inspected to assess if they are functioning as intended and to define any maintenance needs that may be required to encourage continued satisfactory functionality. A professional engineer who is familiar with the design intent of the facility must sign and seal each recertification.

In addition to the SWFWMD's recertification requirements, the USEPA has recently mandated (1990) through the NPDES Municipal Separate Storm Sewer System (MS4) program that select municipalities enhance their existing stormwater management program using a variety of methods. Some of the municipalities already participating in the program include Pinellas County, Hillsborough County, City of Tampa, and the City of St. Petersburg. A detailed section on NPDES is presented later in this section. This EPA NPDES Program will soon be delegated to FDEP in an overall effort to better focus water quality issues to local conditions and unique problems. Sediment and erosion control along with proper maintenance are two principal control factors that FDEP will be focusing on.

Some of these techniques/methods for improving stormwater quality through the NPDES program include regulation and enforcement, development of dedicated funding mechanisms, system inventory and mapping, illicit connection detection and removal, water quality monitoring and modeling, assessment of existing controls, and others. One of the most important requirements involves the development and implementation of maintenance and inspection programs. The goal of the NPDES program is to incrementally improve stormwater quality by encouraging municipalities to become more aware of the problems associated with stormwater and the many practical methods that can be implemented to effect improvements.

A unique aspect of the federal NPDES program is that inspection and maintenance is required on all stormwater facilities regardless of when they were constructed or whether or not they have a state or local permit. As a result, municipalities have begun to assess some of their very old systems that may have been overlooked in the absence of the NPDES mandate. EPA, as described in 40 CFR 122.26(d)(2)(v), requires municipalities to estimate the effectiveness of control measures that are proposed by their Stormwater Management Program. Effectiveness is based upon the estimated reduction of annual stormwater pollutant loadings discharged from the MS4 as a result of a particular control method. The estimation of pollutant reduction associated with source controls is very difficult to accurately quantify. Therefore, in an effort to eliminate wasted time in estimating such reductions, the determination of source control element effectiveness is accomplished through indirect means. Such means include, for example, the volume of trash removed from stormwater management facilities as compared to past volumes removed. Table 11 summarizes accepted inspection and maintenance frequencies for various stormwater systems.

PLOT DATE: 3-22-99




**Tampa Bay National Estuary Program**

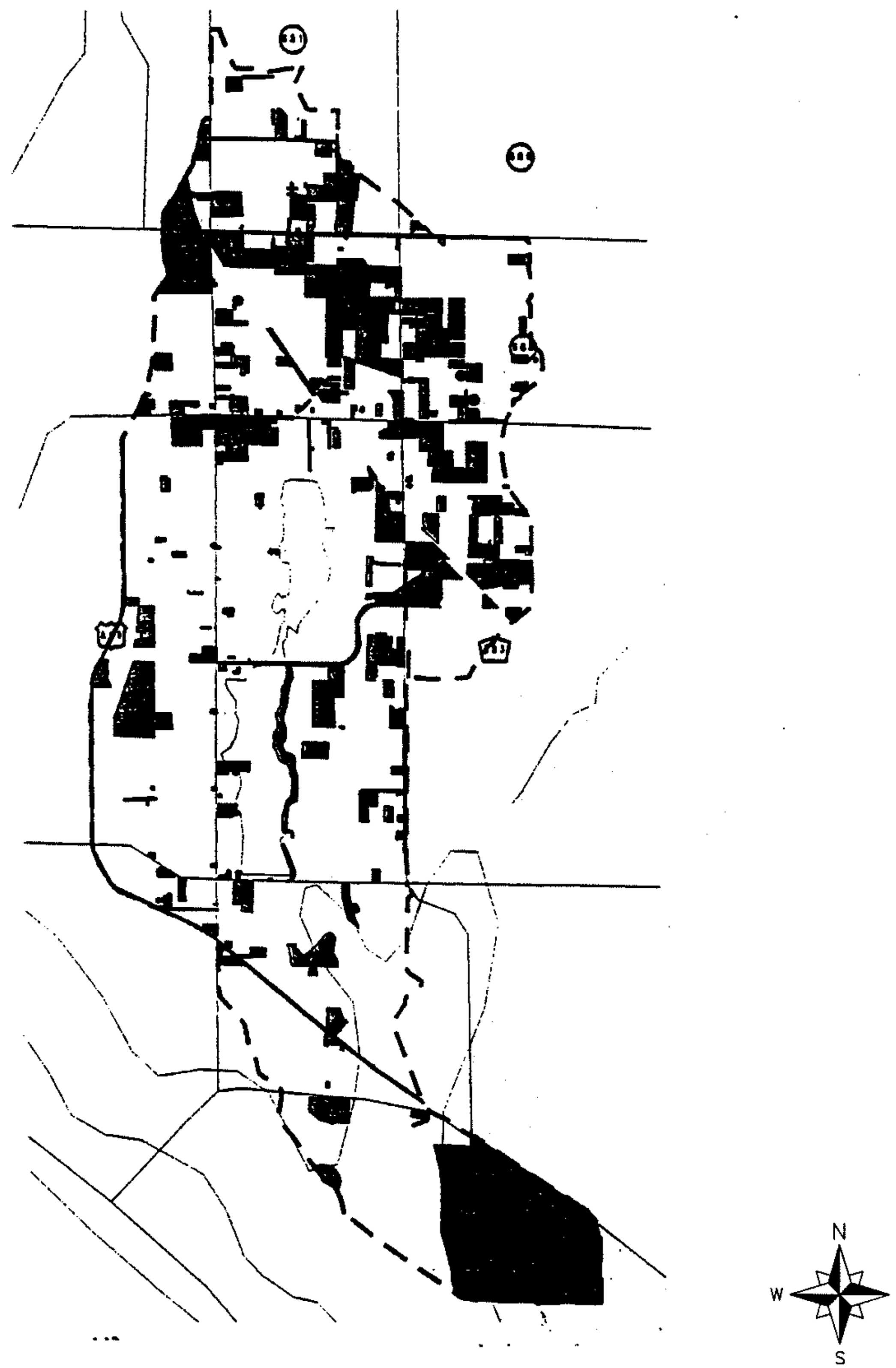
**FIGURE 6**
**AREAS IN DELANY CREEK CURRENTLY SERVED BY PERMITTED STORMWATER MANAGEMENT SYSTEMS**

BCI
ENGINEERS & SCIENTISTS, INC.
2000 E. EDGEWOOD DRIVE, LAKELAND, FL 33803
PHONE: (941) 667-2345

| | | | | |
|---|---|---|---|---|
| DATE: 3-22-99 | REVISED: | DRAWN BY: BJN | SCALE: 1:100,000 | PROJECT NO.: 969566 |

BCI FILE: BCI FILE: N\9566\9566FIG4.DWG

PLOT DATE: 3-22-99




BCI FILE: N\9566\9566FIG5.DWG

BCI ENGINEERS & SCIENTISTS, INC.
2000 E. EDGEWOOD DRIVE, LAKELAND, FL 33803
PHONE: (941) 667-2345

**Tampa Bay National Estuary Program**

**FIGURE 7**
**AREAS IN LONG BAYOU CURRENTLY SERVED BY PERMITTED STORMWATER MANAGEMENT SYSTEMS**

| | | | | |
|---|---|---|---|---|
| DATE: 3-22-99 | REVISED: | DRAWN BY: BJN | SCALE: 1:85,000 | PROJECT NO.: 969566 |

## Table 13

**Recommended Maintenance and Inspection Frequencies**

| Maintenance Item | Maintenance Description | Recommended Inspection Frequency | Minimum Maintenance Frequency |
|---|---|---|---|
| Turf | Mowing | Continuously | As needed per inspection |
| Non Paved Shoulder | Repair | Annually | As needed per inspection |
| Seeding, Mulching, Sodding | Placement | Continuously | As needed to prevent erosion |
| Slope and Ditch | Repair | Continuously | As needed per inspection |
| Drainage Structures | Cleaning | Annually | As needed per inspection |
| Drainage Structures | Repair | Annually | As needed per inspection |
| Storm, Side, Cross Drains | Repair | Annually | As needed per inspection |
| Roadside Ditches | Clean/Reshape | Annually | As needed per inspection |
| Outfall Ditches | Clean/Repair | Annually | As needed per inspection |
| Weed Control – Ponds (first 3 years) | Manual or Mechanical | Quarterly | As needed per inspection |
| Weed Control – Ponds (after 3 years) | Manual or Mechanical | Annually | As needed per inspection |
| Weed and Grass Control | Chemical | Continuously | As needed per inspection |
| Litter Control | Removal | Continuously | As needed per inspection |
| Street Sweeping | Manual or Mechanical | Continuously | As needed per inspection |
| Erosion Protection | Control | Continuously | As needed per inspection |
| Filtration Systems | Replacement of Filter Media | Annually | As needed per inspection |
| Illicit Discharges | Removal | Continuously | As discovered |
| Infiltration Systems | Bottom Tilling | Annually | As needed per inspection |
| Skimmer Structure or Trash Racks/Screens | Oil, Grease and Trash Removal | Quarterly | As needed per inspection |
| Sediment Basins | Dredging or Removal | Annually | As needed per inspection |

In order to assess the degree of maintenance and operation currently afforded existing permitted stormwater facilities, approximately 20 sites were inspected utilizing the criteria generally accepted by the SWFWMD and EPA. Inspection criteria generally focuses on six principal measures including:

- Water quality
- Structural condition
- Aesthetics
- Vegetation cover
- Hydrologic functionality
- Erosion and scour

The sites selected for inspections were intended to represent a varied cross-section of facility characteristics including size, type, land use served, and age. Based on the inspections it is apparent that existing permitted systems are satisfactorily maintained, generally meeting the original design intent.

Based on our extensive experience in the design, construction, maintenance, and inspection of stormwater facilities throughout Florida, it is clear that current regulatory requirements have and continue to make great strides towards improving stormwater quality, particularly for new construction/development. There are, however, several areas where additional controls would be beneficial. Some of these include:

- Requiring or offering credits to municipalities for maximizing the implementation of stormwater management/treatment facilities in redevelopment and road resurfacing projects. Often times, since little additional impervious area is proposed in these types of projects, exemptions or reductions in stormwater treatment requirements are offered by the permitting entities.
- Many facilities were constructed prior to the SWFWMD permitting requirements primarily for the purpose of flood control/attenuation. Often these facilities are not maintained as rigorously as other more recent facilities since the only requirement to effect such an effort is the EPA NPDES regulations. Opportunities to modify these facilities so that they simultaneously provide both water quantity and quality benefits exist and should be further investigated.

- Assign a third party entity to conduct routine inspections of private and publicly owned facilities. Develop and implement stricter enforcement actions for facility owners who fail to satisfactorily operate and maintain their system. Often times a poorly maintained system will affect offsite properties before an impact is readily recognized on the immediate facility site.

### 3.1.4 Street Sweeping

Studies conducted by the Federal Highway Administration (FHWA), USEPA, U.S. Geological Survey (USGS) and various state transportation departments have shown that roadways, including bridges, can act as depositories for significant quantities of contaminants, which may be washed off and transported to adjacent receiving waters during storm events. Studies as early as 1957 documented elevated levels of lead in solids near highways that were felt to be potentially toxic to agricultural crops in the vicinity. Since that time, subsequent studies have shown evidence of high concentrations of heavy metals not only in soils, but also in the urban atmosphere and in receiving bodies of water and streams.

Heavy metals are found to originate not only from the operation of motor vehicles and direct fallout, but also from the pavement materials as well. Sources of metal include gasoline (Pb), exhaust emissions (Pb, Ni), crankcase and lubricating oils (Pb, Ni, Zn), grease (Zn, Pb), tire wear (Cd, Zn), wear on moving bearings (Cu, Pb), decorative and protective coatings (Al, Cd, Cu, Zn, Ni, Fe), brake lining wear (Cu, Cr, Ni), moving engine parts (Fe, Mn, Cr, Co), and asphalt wear (Ni, V).

More recent studies suggest that the majority of particulate contaminants that are deposited on streets are blown to the side by moving vehicles. For example, it has been found that 90 percent of street contaminants accumulate within 12 inches of the curbline of guttered streets.

Municipalities have utilized street sweeping since the "horse and buggy" days for primarily aesthetic purposes. Within the last 15 years sweeping technology has evolved from push broom to high efficiency vacuums. USEPA has suggested, without much proof beyond simple intuition, that street sweeping may be an effective BMP for urban settings and would help to demonstrate compliance with the 1987 CWA. Municipalities are beginning to realize that sweeping operations may be more important than ever; but, as the urgency shifts from appearance to pollution control issues standard sweeping practices and equipment technology must be thoroughly evaluated.

In fact, it has been theorized that an effective sweeping program might be an acceptable alternative to more traditional methods for meeting water quality criteria. Typical stormwater treatment BMPs involve collection and diversion into passive dry retention or wet detention ponds that rely on percolation, quiescent settling, and/or biological processes to remove contaminants. Depending on basin characteristics and system hydrology, such ponds can become quite large.

Historically, perhaps the single largest cost for managing stormwater within municipalities has been the cost for land dedicated to passive treatment of stormwater runoff in retention or detention ponds. For municipalities and state transportation departments, the cost of right of way in the intense urban environment can be so expensive that needed roadway projects may become cost prohibitive.

Recently the Florida Department of Transportation, (District VII office), has proposed to thoroughly study and determine if a carefully managed urban street sweeping program provides for compliance with stormwater quality criteria without the need for traditional quiescent pond systems. The objective is to develop a basis for making sound decisions regarding land acquisition versus sweeping program implementation relative to compliance with stormwater requirements.

A concept model was prepared that compared costs of operating a sweeping program, including the cost of right-of-way acquisition to illustrate the potential benefits. These benefits have been developed on the basis of actual operating costs from various sweeping programs, assumed efficiencies, and right-of-way costs. It is also important to understand that right-of-way costs include not only the price paid per acre but also the costs of condemnation, the loss of tax revenues, and possible business damages.

It is generally undisputed that sweeping has a high value in removing total solids, however street sweeping's value as a pollution control measure remains less clearly defined. Although sweeping is listed by the USEPA as a BMP aiding in the reduction of pollutants in stormwater runoff, there is still no documented testing showing street sweeping is effective in improving water quality. The probable reasons hinge upon three factors:

- Most cities currently don't sweep often enough.
- Sweeping must be performed at a higher efficiency level than the traditional aesthetic approach to do an adequate job of removing the finer particles that tend to be associated with high pollutant concentrations.
- There has not been a carefully managed or monitored approach to sweeping.

For example, some studies have shown that broom sweepers (mechanical) can actually increase the pollutant load on the street. Arguments are that these sweepers remove the heavy-debris (coarse) top layer, exposing and disturbing the more polluted finer particles underneath. These small particles are then more prone to being washed into the storm sewer system with the next rain event. Studies also suggest that even when municipal sweeping is performed using a broom sweeper followed by a vacuum machine, if sweeping is not performed frequently enough or in a properly monitored program, there will be no significant difference in the pollutant removal efficiency. In addition many cities are forced to sweep around cars parked against the curbs. This evidence certainly raises questions about whether current sweeping methods are an effective BMP as defined by EPA.

Recent studies suggest that a monitored frequency is needed to maximize sweeping's effectiveness for reducing pollution in stormwater runoff. For example it would seem to be important that sweeping be performed in a particular pattern defined by the location, and with a sweeper designed to pick up fine particulates. Sweeping must also be performed methodically, and at a speed that adequately captures the finer grained materials.

Illustration of a Sweeping Program

Currently FDOT District VII has contracted USF and BCI in coordination with the City of Tampa to conduct a street sweeping study that will conclude by October 2000. This study is in the development stage and will focus on the following:

- Pollutant removal efficiency of mechanical and vacuum sweeps
- Correlate land use and ideal sweeping frequency
- Effect of sweeping on roadway wear, and
- Comparison of operation and maintenance costs of a street sweeping program vs. a typical stormwater treatment facility
- This on-going study is expected to conclude by October 2000. Until then, attempts for cost comparison should not be considered realistic or reliable.

To illustrate how the sweeping program model might be used, consider a roadway improvement project within a highly urbanized basin area of one square mile (640 acres). Assuming the project involves constructing or adding travel lanes within existing right of way, some type of stormwater treatment system will be required. Typically this might require a pond or series of ponds of more than five acres in size. Within this same basin, let's further assume that there are approximately 40 miles of existing curb and gutter streets.

Under a concept street-sweeping program each mile of roadway would be swept every other week for a sweeping frequency of 25 cycles per year. One of the testing program objectives will be to determine if this frequency is effective.

Research also indicates there is an increasing trend towards use of vacuum sweepers to achieve a higher degree of fine particulate removal since it is known this portion holds the highest pollutant concentrations. However, it is also observed that some programs incorporate additional hand labor sweeping along scheduled routes in order to remove accumulated sediments and excess vegetation. Of course the amount of hand labor is also a function of sweeping frequency as well.

Assuming the frequency is reasonable, implementing a sweeping program within our concept basin will require three sweepers ($91,000.00 ea.); three operators ($18,500.00 annual salary);

operating and maintenance costs ($17,000.00 per sweeper); and administrative and overhead burden (benefits package) costs ($27,750.00 annually). To simplify the analysis, the cost model assumes capital outlays will be amortized over a five-year period for conversion to an annual cost basis. Operational and maintenance costs for typical sweepers are shown in Table 14.

Using these assumptions, the annual cost of a sweeping program in our idealized basin is approximately $244,350.00. If we include the cost for two additional laborers for hand sweeping ($24,000.00 per year each for burdened salaries) the annual costs increase to $292,350.00 or nearly $300,000.00.

With our same idealized basin, we can reasonably assume our roadway project requires an additional five acres of right of way for conventional stormwater treatment ponds. Obviously the number of variables that influence pond sizing can be quite large. Nevertheless, regardless of what the hydraulic requirements for the ponds, we typically find that vacant land in municipal core areas is virtually nonexistent and land that must be acquired is extremely costly even without considering business damages, lost tax revenues and acquisition costs.

Utilizing cost values from Table 15, the cost to provide conventional stormwater treatment on an annualized basis (amortized over 10 years), is approximately $616,900.00. Over and above the tangible costs are those intangible costs attributable to project delays resulting from the time required to obtain right of way through the condemnation process.

**Table 14**
**Operational and Maintenance Costs for Typical Sweepers in the 90's**

| Type Of Sweeper | Expenses | | | | | | |
|---|---|---|---|---|---|---|---|
| | Operator Salary/Yr | Hand Sweeper Salary/Yr | Cost Per Mile | Tires/Yr | Brooms/Yr | Brakes/Yr | Preventive Maintenance/Yr |
| Mechanical | $16,627.20 | $12,479.04 | $14.00 | $229.50 | $1,438.25 | $136.80 | $10,200.00 |
| Vacuum | $18,705.60 | $12,479.04 | $18.00 | $459.00 | $2,615.00 | $144.00 | $14,000.00 |
| Regenerative Air | $18,705.60 | $12,479.04 | $18.00 | $3,521.00 | $2,952.00 | $1,383.00 | $14,000.00 |

Data was provided by The City of St. Petersburg, Florida and some data was assumed.

**Table 15**
**Operational and Maintenance Costs for a Passive Water Quality Stormwater Treatment System**

| Type Of System | Cost | | | | | |
|---|---|---|---|---|---|---|
| | Vacant Land Value / Sf [1] | Improved Land Value / Sf [1] | Acquisition Cost / Sf [1] | Business Damages / Sf [1] | Lost Tax Revenue / Acre / Year | Maintenance/ Yr / Acre [2] |
| Wet Ponds | $20.00 | $150.00 | $4.50 | $10.00 | $75,000.00 | $500.00 |
| Dry Ponds | $20.00 | $150.00 | $4.50 | $10.00 | $75,000.00 | $2000.00 |

Note: 1 Land values are highly variable and the values shown represent gross average values, the same is true for acquisition and business damage costs.
2 Maintenance costs are highly dependent on percentage of ponds with high maintenance needs (such as underdrains), contributing drainage area (sediment load), and other factors.

Conclusions

Although the illustrative example has been simplified for ease of discussion it can be readily seen that high efficiency sweeping appears to be a cost-effective alternative to traditional water treatment in highly urbanized settings. Costs for other BMPs may be found in a research article by Gordon England (1998b).

- Wet/Dry Ponds
- Porous Pavement
- Inlet Weirs
- Baffle Boxes
- Grate Inlet Baskets
- Curb Inlet Baskets
- Sediment Sumps

What remains to be definitively determined is whether a properly designed sweeping program can, in fact, be utilized to satisfy stormwater quality criteria as defined by regulatory agencies. Further, the testing program is intended to demonstrate that a properly designed sweeping program will allow desperately needed roadway improvement projects in highly urban settings to proceed more quickly and at reduced costs if right-of-way acquisition for passive stormwater treatment areas can be reduced or eliminated.

### 3.1.5 National Pollutant Discharge Elimination System (NPDES)

Brief History

NPDES regulations were initially directed towards industrial process wastewater and municipal sewage treatment plant sources of pollution to U.S. water bodies. Effective control of these sources began to be realized in the 1960s and early 1970s. However, non-point sources of pollution, and in particular urban stormwater runoff, were also known to contribute to the degradation of the nation's waterways. Therefore, in 1972, Congress amended federal water pollution control acts and created the Clean Water Act with the intent on controlling all primary sources of water pollution. The Environmental Protection Agency (EPA) followed with the first regulations on stormwater in 1973. These regulations were immediately challenged in court and thus began a long series of legal challenges to federal stormwater regulations.

During the rule-making/revision process, Congress directed EPA to conduct various inventories and studies to quantify stormwater impacts to U.S. water bodies. These studies included the Nationwide Urban Runoff Program (NURP) conducted from 1978 to 1983. A short list of some of these findings for the study years in the late 1970s, include the following:

- 30-40 percent of rivers, lakes, and estuaries do not support their designated use
- 11 percent of impaired river miles is caused by stormwater
- 28 percent of impaired lake acres is caused by stormwater
- 30 percent of impaired estuarine acres is caused by stormwater
- 38 U.S. States reported urban stormwater runoff as a major cause of beneficial use impairment
- Suspended solids in stormwater runoff are an order of magnitude greater than that from secondary sewage treatment
- 78 priority pollutants were detected in at least 10 percent of the discharge samples, which were tested for them
- 59 percent of shellfish harvest limited areas in the Gulf of Mexico are affected by stormwater runoff

Finally in 1987, Congress directed EPA to regulate several classes of stormwater discharges. Municipal Separate Storm Sewer Systems (MS4s) serving populations over 100,000 were among the regulated classes. EPA in conjunction with FDEP is in the process of formalizing Phase II NPDES MS4 regulations that will further improve the programs overall function. Some of the changes to the program may include:

- Developing and accommodating Total Maximum Daily Load Limits (TMDL), to select receiving water bodies
- Increasing overall awareness of key BMP elements
- Delegation of program to local level to encourage consideration of specific and unique conditions

- Lowering of population density from 100,000 to 10,000
- Development of a "Tool Kit" to aid municipalities in program setup and long term implementation

Industrially classified businesses were another regulated class of stormwater discharges. The regulations were finally published in November 1990, with several subsequent rule adoptions for industries occurring since that date. It is these classes of regulated discharges and the nature of the regulations that are discussed relative to the TBNEP project.

### 3.1.6 Impact of NPDES Stormwater Regulations

Industries

Industries qualify for regulation under the NPDES stormwater regulations based on their Standard Industrial Classification (SIC) code. These industry groupings were chosen for regulation based on the potential for their stormwater runoff to adversely impact receiving water bodies. This rule affects many businesses as noted on Table 16, which is an excerpt from the NPDES stormwater regulations. Issues such as raw materials, typical materials handling/processing practices, waste stream and by-product generation, and typical storage practices were considered prior to an industry group's inclusion under the regulations.

## Table 16
## Facilities Affected by NPDES

| | |
|---|---|
| (i) | Facilities subject to stormwater effluent limitations guidelines, new source performance standards, or toxic pollutant effluent standards under 40 CFR Subchapter N (except facilities with toxic pollutant effluent standards which are exempted under category (xi) below); (See Table 3.3.6-3) |
| (ii) | Facilities classified as Standard Industrial Classifications 24 (except 2434), 26 (except 265 and 267), 28 (except 283 and 285) 29, 311, 32 (except 323), 33, 3441, 373; |
| (iii) | Facilities classified as Standard Industrial Classifications 10 through 14 (mineral industry) including active and inactive mining operations (except for areas of coal mining operations no longer meeting the definition of a reclamation area under 40 CFR 434.11(l) because the performance bond issued to the facility by the appropriate SMCRA authority has been released, or except for areas of non-coal mining operations which have been released from applicable State or Federal reclamation requirements after December 17, 1990 and oil and gas exploration, production, processing, or treatment operations, or transmission facilities that discharge stormwater contaminated by contact with or that has come into contact with, any overburden, raw material, intermediate products, finished products, byproducts or waste products located on the site of such operations; (inactive mining operations are mining sites that are not being actively mined, but which have an identifiable owner/operator; inactive mining sites do not include sites where mining claims are being maintained prior to disturbances associated with the extraction, beneficiation, or processing of mined materials, nor sites where minimal activities are undertaken for the sole purpose of maintaining a mining claim); |
| (iv) | Hazardous waste treatment, storage, or disposal facilities, including those that are operating under interim status or a permit under Subtitle C of RCRA; |
| (v) | Landfills, land application sites, and open dumps that receive or have received any industrial wastes (waste that is received from any of the facilities described under this subsection) including those that are subject to regulation under Subtitle D of RCRA; |
| (vi) | Facilities involved in the recycling of materials, including metal scrap yards, battery reclaimers, salvage yards, and automobile junkyards, including but limited to those classified as Standard Industrial Classification 5015 and 5093; |
| (vii) | Steam electric power generating facilities, including coal handling sites; |
| (viii) | Transportation facilities classified as Standard Industrial Classifications 40, 41, 42 (except 4221-25), 43, 44, 45, and 5171 which have vehicle maintenance shops, equipment cleaning operations, or airport deicing operations. Only those portions of the facility that are either involved in vehicle maintenance (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication), equipment cleaning operations, airport deicing operations, or which are otherwise identified under paragraphs (i)-(vii) or (ix)-(xi) of this subsection are associated with industrial activity; |
| (ix) | Treatment works treating domestic sewage or any other sewage sludge or wastewater treatment device or system, used in the storage treatment, recycling, and reclamation of municipal or domestic sewage, including land dedicated to the disposal of sewage sludge that are located within the confines of the facility, with a design flow of 1.0 mgd or more, or required to have an approved pretreatment program under 40 CFR 403. Not included are farm lands, domestic gardens or lands used for sludge management where sludge is beneficially reused and which are not physically located in the confines of the facility, or areas that are in compliance with Section 405 of the CWA; |
| (x) | Construction activity including clearing, grading and excavation activities except: operations that result in the disturbance of less than five acres of total land area which are not part of a larger common plan of development or sale; |
| (xi) | Facilities under Standard Industrial Classifications 20, 21, 22, 23, 2434, 25, 265, 267, 27, 283, 285, 30, 31 (except 311), 323, 34 (except 3441), 35, 36, 37 (except 373), 38, 39, 4221-25, (and which are not otherwise included within categories (ii)-(x)). |

(Reprinted from "Guidance Manual for the Preparation of NPDES Permit Applications for Stormwater Discharge Associated with Industrial Activity", EPA, April 1991)

The rule requirement probably having the most impact on the quality of stormwater discharges reaching Tampa Bay from industries is the requirement for a stormwater pollution prevention plan (SWPPP). This rule requirement forced regulated businesses to take a careful look at their sites and their present management strategies and to address the following:

- Do we have any plans which address pollution control and who should be responsible for maintaining our site in compliance with NPDES regulations?
- Do we have an up-to-date site map showing the location of stormwater outfalls, drainage basin divides, and exposed materials?
- What are our present management practices (structural and non-structural) and what additional BMPs can we implement and when?
- Evaluate individual pollutant sources at site, associated risks, and BMPs to minimize impacts to stormwater runoff quality
- Employee training
- Annually assess the SWPPP, maintain records, and revise plans as needed

With the implementation of the SWPPP by the industries, reduced pollutant loads to receiving systems, whether they are MS4s or natural receiving water bodies including Tampa Bay, should be realized. However this requires actual implementation of the SWPPP which, in many cases, may vary from municipality to municipality. Why? Depending on how individual municipalities implement their NPDES programs, the "level of checking" industry SWPPP implementation will vary widely and this is further discussed under the MS4 section below.

Municipal Storm Sewer Systems

Municipalities surrounding Tampa Bay are subject to the NPDES stormwater regulations. The Cities of St. Petersburg and Tampa, the Counties of Pasco, Polk, Pinellas, Hillsborough, and Manatee (inclusive of municipalities) and the Florida Department of Transportation (FDOT) have all received their permits for discharging stormwater from their MS4s into U.S. waters. How compliance with these permits will ultimately affect the quality of stormwater discharging to Tampa Bay is not readily quantifiable.

The mechanism each municipality has to improve the quality of its stormwater discharges is the stormwater management plan it implements under the NPDES permit. During the NPDES application preparation phase, the municipalities had to document all activities that affected the quality of stormwater discharging from their MS4s. Of these activities, most of the management plan elements of the municipalities include predominantly public education and non-structural BMP efforts as further detailed below.

What the NPDES permitting process did for most municipalities was to force them to look at many of their day-to-day activities on a stormwater management basis. Documentation of such practices as stormwater regulations on new development, street sweeping, pesticide/herbicide and fertilizer application, roadway maintenance, ditch cleaning, stormwater facility inspection and maintenance, litter control, illegal sewer connection inspection, and employee training had to be addressed. As such, some of the municipalities' past practices may be subject to revision based on the findings during the NPDES permit application and implementation stage.

### 3.1.7 Public Education

In 1996, NPDES permittees, in an effort to stretch their public education funds and to share information, formed an NPDES Public Education Subcommittee, which is coordinated through the Tampa Bay Regional Planning Council. This Subcommittee consists of the area's NPDES municipalities from Pasco, Polk, Pinellas, Hillsborough, and Manatee Counties and FDOT. The Subcommittee has prepared a list of potential public education projects that address stormwater, how people activities directly and indirectly impact water and ways the general public can help reduce pollution.

The Subcommittee has ranked projects according to such criteria as the ability and degree of reaching a bay area wide audience; ability to directly and indirectly improve knowledge of how daily activities impact surface water quality; allow for public participation; and the frequency of the education element. Thus far, funded projects include such projects as those shown in Table 17.

**Table 17**
**Public Education Projects and Costs**

| Projects | Cost |
|---|---|
| Storm drain inlets stenciling | $ 2.00/Stencil |
| Revision and broadcast of a stormwater educational video on a broadcast station and government access stations | $ 55,000.00 |
| Florida Yards and Neighborhoods (FYN) Point of Purchase Campaign | $ 15,000.00 |
| Tampa Bay Repair Kit Revision and Reproduction | $ 15,000.00 |

Anticipated future projects include sponsorship of the Officer Snook program, an educational presentation to preschool and elementary students which focuses on water pollution; sponsorship of Museum of Science and Industry's (MOSI) Marine Gang program, an environmental awareness performance by MOSI staff to elementary school students and at other events; Enviroscape Model Watershed distribution to various groups for use at functions to show how pollutants move through a watershed; public service announcements on radio; and pesticide education to government employees.

Assessing the exposure of some public education programs is relatively easy. The number of students observing an environmental skit, or the number of observations at a display can be readily quantified. This information gathering is often a condition to funding by funding source agencies. However, corresponding these numbers into pollutant discharge volume reductions is not easily calculated. Social behavior studies have been conducted and have identified certain levels of awareness as well as categorized group tendencies. In the absence of this information, there are some indicators that may potentially be used to make assessments on the impact of public education efforts. Factors such as, antecedent weather and structural control implementation within watersheds may alter the usefulness of this information.

- Litter collection associated with routine maintenance activities (such as mowing and street sweeping) by government forces or their contractors.
- Litter collection composition during special event projects.
- General observance of trash along shorelines.
- Observations made during routine inspection of stormwater management facilities.

- Observations made during dry weather field screening of stormwater outfalls.
- Observations made during routine storm sewer maintenance such as pipe desilting and inlet cleaning.

### 3.2 End-of-Pipe Retrofits to Existing Structures

Stormwater runoff contains many pollutants, but the more common ones target the removal of floating debris (such as grass clipping and leaves), suspended solids, heavy metal, hydrocarbons and nutrients (specifically nitrogen and phosphorus). Though floating debris and other suspended solids are not typically tested for pollutants during most analyses, solids can be either an inherent source of pollutants, particularly nutrients and metals, or provide a surface for pollutant adsorption.

Increased environmental awareness to treat stormwater coupled with mandates such as the NPDES has resulted in the need for municipalities to seek new and innovative approaches to improving stormwater quality. This task is complicated by the fact that many municipalities are highly developed and therefore lack sufficient land to create the more traditional stormwater treatment systems such as retention/detention ponds or alum treatment systems.

In an effort to face this challenge, Brevard County's Stormwater Utility (Gordon England, 1998a 1998b) utilized EPA grants to install and test three treatment devices: baffle box, grate inlet basket, and curb inlet basket within the Indian River Lagoon system. These devices may be constructed in existing manholes, inlets, or pipes and therefore require very little to no additional land purchase to construct. Further description of these end-of-pipe retrofits are described in Appendix B.

Tables 18 below summarizes the data collected during the three year study period, including some of the costs associated with sediment and nutrient removal.

**Table 18**
**Data and Costs Associated with End-of-Pipe BMPs Studied in the Indian River Lagoon**

| Type of BMP | Number Installed | Average Weight Cleaned kg/Unit BMP | Average Cost/Cleaning Unit BMP | Average Cost/lb. Sediment Removal | Average Cost/lb. TP Removal | Average Cost/lb. TN Removal |
|---|---|---|---|---|---|---|
| Baffle Box | 24 | 1925 | $ 450 | $ 0.11 | | |
| Inlet Weir | 40 | 2.76 | $ 3.50 | | | |
| Grate Inlet Basket | 30 | 16.3 | $ 45 | $ 1.25 | | |
| Curb Inlet Basket | 68 | 4.6 | $ 3.50 | | $ 8.54 | $ 3.33 |
| Sediment Traps | 13 | 101.6 | $ 6 | | | |

Maintenance record for 24 baffle boxes showed a removal of 202 cubic meters of sediment removal over three years. The sediment removal rate varied greatly ranging from 5.9 kg/cleanout to 17,796 kg/cleanout. The lowest yearly removal record was 18 kg from a residential drainage basin of 0.1 acres whereas the highest yearly removal was 100,633 kg from a 63-acre drainage basin that had a highly eroded open channel upstream. Baffle boxes were very effective in removing sediments and floating debris, but had limited effectiveness in removing nutrients (data not reported). A vacuum truck can typically clean two baffle boxes per day which costs about $450 per box or about $0.24 per kg of sediment removed. Baffle boxes are a preferred BMP alternative when the need for sediment removal is expected. This may also indirectly be effective in removal of COCs due to their sorption onto sediments.

The grate inlet baskets proved very effective in collecting significant quantities of leaves and other floating trash. Hydrocarbon absorbing booms were also tested; however, their efficiency could not be determined, but were replaced every three to four months. It was determined that oil booms were only cost effective in high hydrocarbon loading areas such as parking lots and commercial areas.

Curb inlet baskets were effective in trapping yard wastes and other floating trash. Almost 50 percent of the loading weight was that of grass and leaves. Though these baskets were not designed to trap sediments, several inches of sediments were observed on occasions, but data was not recorded.

Cleanout frequency is dictated by rainfall frequency, land use and drainage basin size. It was noted that in residential areas, the inlet areas were conveniently utilized to pile yard waste for pickup, thus showing higher loadings. This points out the importance of public education as a component of pollution reduction.

There are no universal fixes for stormwater pollution control. Each drainage basin must be analyzed for types of pollutants and loadings and targeted removal. Inlet baskets are affordable alternatives to stormwater treatment, but the tradeoff is perpetual maintenance costs. The Indian River Lagoon experience points out that scheduling and tracking maintenance of these retrofits is a demanding job. A dedicated source of manpower, equipment, and funding needs to be allocated to maintain these retrofits for them to be effective BMPs, just like roads and wastewater plans need maintenance.

## 3.3 Conceptual Regional Stormwater Treatment Facility

Best management practices for improving the water quality discharged from Delaney Creek to Tampa Bay could include source and structural controls. However, obtaining successful source control throughout the entire watershed is unlikely because it would be very dependent on cooperation of all human operations. The incentives for this cooperation do not exist at the present time. Thus the use of structural controls becomes a necessary component of the watershed improvements.

The Delaney Creek watershed is intensively developed in a vast majority of its area. Efforts were made to site a potential conceptual regional treatment facility for the watershed. Retention/Detention facilities are generally recognized as the primary method of pollutant removal in large scale applications. Traditional BMPs are most often designed and monitored for maximizing removal efficiency of nutrients, suspended solids, and select metals. Correlations have been established between total suspended solids and a few metal parameters such as Lead and Iron. Literature regarding defined relationships between BMP types and COC removal is limited. However, previous studies consistently emphasize control of TSS as an effective method of removing COC from stormwater discharges. COC management is more often associated with some control such as point of discharge control, illicit discharge removal, etc. Due to the limitations on land availability in close proximity to Tampa Bay, if a regional treatment system approach was taken, siting of the facility would most likely occur in the lower one-third of the system.

Offline stormwater treatment systems for a large watershed are typically permanently wet due to base flow contribution, control elevations of the facility relative to the stream channel and characteristics of the soils located at the potential sites. Various wet stormwater system designs are presently used to improve the water quality of the discharge from a contributing drainage catchment area, as follows:

- Facility is placed "offline" of the primary conveyance channel. This allows base flow and flows from select storm events to be routed through the treatment facility for pollutant uptake through various removal mechanisms. Flows from more significant storm events are allowed to travel the natural conveyance, bypassing the facility to prevent potential reintroduction of pollutants from the facility into the downstream system.
- Sedimentation capacity near the outfall into the facility. This "sump" will be sized for long term-operation and to facilitate maintenance.
- Has designed flexibility for periodic maintenance of select portions of the facility.
- Most effective when the permanent pool volume provides a hydraulic detention time of at least two weeks. Accepted definition of hydraulic retention time is the ratio of permanent pool volume to the theoretical volume of stormwater runoff for a given year, based on mean storm events.
- Most effective when the permanent pool volume is equal to 0.5 to 1.0 inch of stormwater runoff from the contributing impervious watershed area.
- Most effective if the detention time for the design detention volume is 24 hours.

- The vegetated area of the system should equal or exceed two percent of the watershed area.
- Recommended maximum loading rates for vegetated wet detention systems are 222-666 lbs. total nitrogen per acre per year.
- Water level fluctuations in the facility allow for a varied range of pooling depths in the vegetated areas.
- Has habitat conducive to fish, waterfowl and wildlife habitat.
- Is conducive to effective public education efforts.
- Aesthetically fits into the surrounding landscape.

Success in the removal of specific COCs from the water column of surface water flows using conventional structural BMPs has not advanced as has the removal of nutrients. The present default approach to retaining COCs has been through retention design for suspended solids due to COC tendency for adhering to suspended fine particulates. The Delaney Creek concept regional facility can be designed to remove a majority of the suspended solids for the water column through the inclusion of various design criteria that maximizes reduction of suspended solids in the system effluent

A conceptual regional offline treatment facility is potentially available in the lower one-third of the watershed. At this location, the contributing drainage area of the basin is 8800± acres. Land use distribution for this location is as indicated in Table 6. This table summarizes some of the sizing requirements for the concept facility. No adjustments have been made to remove isolated closed sub-basins from the total catchment area nor have any credits been made for areas served by stormwater treatment facilities.

**Table 19**
**Concept Facility Sizing Guidelines**

| Facility Sizing Criteria | Required Size Based on Concept Location | Notes/ Assumptions |
|---|---|---|
| Total Nitrogen Loading Limitation (222-666) lb./Ac/Yr. | 75 to 225 acres | Source of Loading: 70%± of values from Table A-1, Toxic Contamination Sources Assessment, Parsons Eng. Sciences, Inc. (July 97) * |
| Hydraulic Residence Time of 2 weeks | 190 Ac-Ft | Mean event of 0.5"; Effective runoff coefficient of 0.1 |
| Facility Area > 2% of Watershed Area | 175 acres | |
| Detention Time of Detention Volume is >24 hours | - | Local criteria (SWFWMD) is sufficient |

* Consistent with range of observed loads from USGS Study, Water Resources Investigations Report 95-4167 (1996).

An existing borrow area located at the concept site will provide for sedimentation and a majority of the required permanent pool volume. However, areas adjacent to the existing pit would have to be excavated to provide the shallow areas for vegetative growth.

Load reduction benefits for an extended wet detention system can vary significantly. Load reduction for total nitrogen can be estimated at 30 percent to 70 percent and for total phosphorus at 40 percent to 80 percent, with the higher ranges more likely to be achieved if the design guidelines are followed. Based on the observed loads from previous reports, potential load reduction range from three to 20 tons/year total nitrogen and two to 15 tons/year total phosphorus.

The concept facility would be effective at removing the basin's priority metals, dependent on the final area and characteristics of the system. There is insufficient information showing definitive trends in the removal of other COCs; however, removal does occur based on analyses of sediments from conveyance systems and BMP systems

**Table 20**

**Potential COC Removal by Concept Facility**

| Pollutant Parameter Grouping | Estimated Annual Load (Tons) | Estimated Removal Percentage (%) | Estimated Annual Load Reduction (Tons) |
|---|---|---|---|
| Metals (Cr,Cu,Hg) | 2132 | 20-80% | 426-1705 |

Estimated costs associated with the concept facility are outlined in Table 20.

**Table 21**
**Estimated Concept Facility Costs**

| Activity | Estimated Cost | Notes/Assumptions |
|---|---|---|
| Land Acquisition | $4,500,000 | 75 Acres at $60,000/Acre: quotes range from $40,000 to $320,000/acre |
| Design & Permitting | $150,000 | |
| Construction- Site Work | $1,000,000 | Potential for borrow material sale to reduce this cost; assume existing borrow area available for majority of permanent pool |
| Construction- Structures | $200,000 | |
| Construction- Select Planting | $50,000 | |
| **Estimated Total Costs** | **$5,900,000** | |

The limitations on readily available and affordable land for construction of a regional treatment facility are great. Should this option be chosen, it is likely that the size of the facility would be restricted based on land costs alone, resulting in a higher net loading rate on the facility and reduced removal efficiencies. Provisions for facilitating periodic maintenance will be critical to the long-term success of the project. This may include periodic removal of vegetative biomass and detritus.

### 3.4 Sediment Removal and Cost Considerations

Though many of the retrofit projects and other structural measures have been put in place to preclude sediments from reaching the Bay, sediments that already exist in the water bodies that ultimately discharge into the Bay from the two sub-basis may require removal. In many instances the sediments themselves have been identified as a source of pollution to the water column above it, therefore, removal of sediments may need to be considered.

There are several considerations for dredging sediments from water bodies once it is determined that dredging is the necessary option. Some of these considerations and costs are:

Mobilization/Demobilization

Mobilization and demobilization charges represent the costs for the contractor to move and set up the equipment at the dredge site and, upon completion of the project, to dismantle and move the equipment from the site. These costs will vary greatly, depending on the site location relative to the contractor's base of operations. Mobilization/demobilization costs represent 10 to 15 percent of the total project cost.

Dredging

Dredging costs include excavation of the material from the bottom of a water body and transporting it to a dewatering site. Generally, as the volume of sediments to dredge increases, the cost per volume decreases, but is also dependent on the type of dredging, hydraulic or mechanical. Hydraulic dredging costs range from $1.00 to $8.00 per cubic yard. Dredging costs using a suction dredge range from $1.00 to $3.00, whereas those for a cutter head range from $5.00 to $8.00. Mechanical dredging costs are comparable to hydraulic dredging, but could be higher if the dredged material requires multiple handling, which is dictated by the access to the dredge site. Table 21 represents the cost for actual dredging from several on-going or completed projects.

**Table 22**
**Costs from Various Projects for Actual Hydraulic Dredging Muck Sediments ***

| Water Body | c.y. (000's) | $/c.y. |
|---|---|---|
| Banana Lake, Lakeland, FL | 1,000 | 1.00 |
| Lake Hollingsworth, Lakeland, FL | 3,600 | 0.80 |
| Sippo Lake, Canton, OH | 300 | 1.50 |
| Crane Creek, Melbourne, FL | 90 | 2.71 |
| Turkey Creek, Palm Bay, FL | 380 | 2.73 |

*Note: Does not include mobilization/demobilization & disposal area construction costs.

Cost of Dewatering Site

To minimize pumping and other transportation costs, the dewatering site should be located as close to the dredging area as possible. Unfortunately, the closer property is located to water, generally, the more expensive it becomes. A raw land cost of $25,000 to $35,000 per acre and upwards would not be considered unusual for certain locations. If land application is selected as the final disposal alternative, the dewatering site may also serve as the final disposal site. This may substantially reduce per unit costs.

Dewatering Site Preparation

Dewatering site preparation includes clearing and grubbing, grading, berm construction, and installation of weirs and turbidity control equipment. Costs may range from $2,000 to $6,000 per acre, depending on the existing vegetative cover.

Dewatering the Sediment

Assuming a hydraulic dredge is used, the sediment must be dewatered due to the large volume of water (80 percent or more) mixed with the sediment. To accomplish rapid dewatering, chemical flocculants are often used. This has only recently been utilized in dredging projects, necessitated by a lack of sufficient land area available in highly urbanized coastal areas. The chemical flocculants not only increase dewatering, but also increase clarification of the water so that it may be safely discharged into a water body.

If dredging is performed by mechanical equipment such as a clamshell dredge, the sediment may be loaded directly into dump trucks and transported directly to the final disposal site. This is due to the higher solids content of mechanically dredged material (up to 90 percent), compared with hydraulically dredged sediment.

Final Disposal

Final disposal costs include the handling and transportation of the dewatered material to the final disposal location if different than the dewatering site. The primary equipment used for loading and transporting dewatered muck is a front-end loader, a bulldozer and dump trucks. Typical hourly rates for this equipment, including driver and fuel are:

| | | |
|---|---|---|
| front end loader | = | \$55-\$60 per hour; |
| bulldozer | = | \$55-\$60 per hour; and |
| dump truck | = | \$ 36-\$40 per hour |

The costs discussed above are presented to give typical ranges and values for the various aspects of a dredging project. However, each dredging project is unique and costs can vary significantly based on factors such as; type of dredge, availability and cost of upland disposal area, proximity of disposal area, environmental monitoring (permit), testing requirements, and the quantity of sediment to be dredged. Generally, as the volume of sediments to be removed increases the overall dredging cost per volume decreases as shown in Table 21.

One other aspect that should be considered prior to beginning a dredging project is the potential value or beneficial uses for the dredged materials. An investigation and demonstration study (BCI, 1996) on the beneficial uses of sediments from the Indian River Lagoon showed promise for use of organic "muck" sediments not only in the horticultural and golf course industries, but could also be applicable to other roadway or landscaping projects. Separation of sediments during dredging process, using hydrocyclones, is also being considered as an option to further enhance the quality and beneficial uses. Hydrocyclones are utilized to separate the fine and coarse fractions of the sediments such that the coarse fraction, mostly sand, can be utilized as a construction fill material whereas the finer fraction, consisting mostly of clay, silt, and organic matter can be used in green spaces.

## 4.0 SUMMARY OF OPTIONS, CONCLUSIONS AND RECOMMENDATIONS

It is apparent from the land use maps of the two sub-basins that Long Bayou is highly built-up compared to Delaney Creek. This characteristic generally limits the use of traditional structural stormwater management controls: retention, detention, and filtration. In addition, it is apparent that Delaney Creek has substantially greater agricultural land use than Long Bayou, which is demonstrated, by the higher levels of predicted pesticide loading. In general, the point sources appear to be more accurately defined in the Long Bayou basin than in the Delaney Creek basin.

However, existing permitted stormwater facilities in both sub-basins appear to be satisfactorily maintained. Regardless of the land-use status, a total of three projects were identified in the current management action plans for both sub-basins. It is evident that local and state governments along with other environmental groups like Agency on Bay Management have identified other sub-basins as areas of priority.

Based on our meetings, field reconnaissance, and review of existing reports the following conclusions were reached by this investigation:

- Accuracy of existing databases for point sources, should be improved and properly maintained. Based on review and field siting of alleged facilities it is apparent that much of the existing data sources are in need of updating.
- Based on our field inspection of numerous facilities representing a diverse cross-section of facility types and land characteristics served, the existing stormwater management facilities appear to be adequately maintained as needed to sustain intended functionality. Some degree of further encouragement can be offered to municipalities and private industry using the following techniques.
    - Requiring or offering credits to municipalities for maximizing the implementation of stormwater management/ treatment facilities in redevelopment and road resurfacing projects.
    - Provide benefits to entities proposing to modify existing (pre-regulation) facilities so that they simultaneously provide both water quantity and quality benefits.

- Assign a third party entity to conduct routine inspections of private and publicly owned facilities. Develop and implement stricter enforcement actions for facility owners who fail to satisfactorily operate and maintain their system.

- Most sources of COCs have been controlled by regulation (EPA NPDES, Water Management Districts, and FDEP); particularly over the last 10 years. This trend is expected to continue and likely improve over the next five years as Total Maximum Daily Load Limits (TMDLs) are established and implemented.
- Consider using various end-of-pipe BMP treatments in areas that are built-out and do not have the luxury of land to construct the more traditional retention/detention type facilities. While these types of treatments have been shown to be somewhat effective in removing TSS, the costs of installation may be prohibitive when compared to the benefit provided.
- Opportunities exist to improve stormwater quality during construction (i.e. temporary controls) and redevelopment activities (permanent controls). Regulations should be developed at the municipal and County level to require a certain degree of water quality improvement for all projects.
- Street sweeping is currently under evaluation and appears to be a viable option to improve stormwater quality. The primary goal of establishing a rigorous street-sweeping program is to offset the need to install and construct additional retention/detention facilities as required to demonstrate an improvement in overall water quality.
- Public education programs are a cost-effective approach to stormwater quality improvement and should continue. The most notable problem associated with implementing a public education program is in measuring the programs effectiveness. Some possible measures might include: degree of public concern, litter collection, fertilizer and pesticide usage, general observations, or long-term-monitoring of isolated basin areas.
- Opportunities for establishing Regional Stormwater Treatment Systems exist within the Delaney Creek basin, but are very expensive due to limited availability and high cost of land. In addition, limited data is available for sizing these types of facilities

from the standpoint of COC removal - not to mention the lack of data for use in defining COC removal efficiencies. Typically these types of systems are designed/sized and efficiencies estimated based on nutrient and TSS removal. It has; however, been demonstrated that COCs can be removed or attenuated via the physical, chemical and biological mechanisms common to typical retention/detention facilities.

- Improved monitoring programs should be developed and implemented to better characterize and identify long term water quality trends of surface water sources entering the Bay. This information will become priceless in support of satisfying TMDL limits and documenting trends in water quality improvement.
- Enforcement and follow-up inspection of all construction activities should be emphasized. Regulatory agencies should require that erosion and sediment control activities have well defined pay item quantities in addition to specific installation and continuous inspection requirements for all new construction, redevelopment, and maintenance work.
- Underground Storage Tank clean up needs to be better prioritized and expedited where contaminants are suspected of being mobile. Since the majority of documented contaminants consist of petroleum products, the ability for pollutants to migrate is high - particularly in the case of the more refined fuels such as gasoline.
- Existing Bay sediment contamination is likely due to past industrial and associated land use activities as indicated by historical regulatory documentation. Radioisotope techniques are a potential analytical method for determining the age of existing sediments; however, this is a costly option.
- Fine-grained and organic-bearing sediments are a potential source of contaminants to the Bay. Based on limited lake sediment removal studies it is likely that the sediments are a potential contributing source of COCs to the Bay. Dredging is a viable option for removing these sediments. One option in lieu of sediment removal, specifically contaminated sediments, could be through "capping" or covering using cleaner soil material.
- Improve coordination between governing entities; TBNEP, SWFWMD, County, Agency on Bay Management, etc. Establish cooperative effort in identifying and

prioritizing sub-basin(s) for future water quality work. Develop a consensus on action plan implementation and funding source identification/contribution. Maximize use of existing resources – both monetary and labor. A well coordinated level of cooperation between the various government entities that discharge surface water to the Bay will become instrumental in satisfying the requirements of TMDLs limits.

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# APPENDIX A

## Structural and Non-structural Control Measures

## Structural Control Measures

Structural controls consist of permanent or temporary control measures that require physical construction for implementation. Structural controls generally rely on the following treatment mechanisms:

- Detention/Retention
- Infiltration
- Filtration

<u>Extended (Dry) Detention Pond</u>

An extended detention pond is a stormwater management technique, which temporarily detains stormwater runoff for up to 48 hours after a storm thus allowing sediments to settle out. Discharge from the pond occurs gradually via a fixed opening thereby providing peak flow attenuation as well. The pond is normally dry between storm events and has no permanent standing water.

This pond provides moderate but variable removal of particulate pollutants and negligible removal of soluble pollutants. Other characteristics/factors include:

- Contributing watershed area should be > 10 acres.
- Not appropriate for high visibility areas unless frequently maintained.
- Water table should be > 2 feet below pond bottom.
- Use in urban areas limited due to space constraints.
- Re-suspension of previously deposited pollutants can occur.
- Minimum detention time is six to twelve hours.
- Clogging of drawdown (ED control) device is common.
- Works most efficiently with smaller treatment volumes.
- Provides very little wildlife habitat value.
- High routine maintenance requirement for sediment cleanout, ED controls device and mowing.

- Pollutant removal efficiency highly dependent on design treatment volume, watershed impervious area distribution, pond configuration and maintenance frequency.
- Often used as a retrofit option such as for dry stormwater ponds or at drainage conveyance confluence's.

Wet Ponds

A wet pond is a widely used stormwater treatment and storage method which consists of a permanent pool of water located at or below a control structure release or overflow elevation. Wet ponds provide moderate to high removal efficiencies of particulate and soluble pollutants as well as peak flow attenuation. Removal rates are effective when the permanent pools are designed with volumes of 0.5 to 1.0 inch of runoff from the contributing impervious watershed area. Other characteristics and/or factors to consider include:

- Requires regular sediment removal to provide continued pollutant removal efficiency.
- Requires frequent maintenance to preserve aesthetics and function.
- Contributing watershed area needs to be > 10 acres or a reliable baseflow is needed to prevent pool stagnation.
- Pond must be carefully located and designed to reduce adverse downstream impacts from pond discharge.
- Pretreatment by sediment sump is needed.
- Provides good fish and wildlife habitat value.
- Can be used to serve large developed sites and can double as a recreational facility.
- Potential for thermal polluted and oxygen depleted discharge if improperly designed.
- Space limitations in urban areas are high but the aesthetic nature of properly maintained ponds is advantageous for recreational areas.
- Retrofit capability is high for improperly functioning/designed dry ponds, also commonly used in conjunction with wetlands and extended detention techniques (wet detention ponds).

- When relatively poor draining soils occur, pond is not limited by depth to water table - when located in good draining soils, pond must be located below ground water table.

Stormwater Wetlands

Stormwater wetland systems consist of shallow, man-made pools of water designed to promote the growth of marsh and hardwood vegetation and to remove pollutants through sedimentation, adsorption, physical filtration, microbial decomposition and plant uptake.

Stormwater wetlands have a high pollutant removal capability similar to wet ponds. Phosphorus removal is variable depending on the biomass volume, the treatment volume, surface area to volume ratio and wetland surface area to watershed area. Additional characteristics are as follows:

- Maintenance is high initially to establish the wetland coverage and diversity. After the first three years the maintenance is more consistent to other pond designs such as sediment removal and mowing of fringe areas.
- Aesthetically pleasing when properly designed, constructed, and maintained.
- If located and designed improperly, can adversely impact downstream systems and/or adjacent natural areas.
- Requires sediment sump at inflow point.
- Nutrient removal rate during die back or non-growing season is generally poor and can release nutrients under certain conditions.
- Wetland area should be > 2 percent of watershed area and watershed should be > 5 acres.
- Increasing detention time increases pollutant removal efficiency.
- Reliable ground water inflow or baseflow is necessary to ensure wetland vitality.
- Space limitations are significant because of the necessary shallow depth.
- Stormwater detention can be utilized contingent on limiting fluctuations to acceptable ranges relative to plant needs.

- Provides habitat for wildlife and waterfowl.
- High maintenance relative to control of nuisance species is possible.
- Bacterial contamination is possible if waterfowl become overabundant.
- Wetland biota is possibly impacted by trace metal uptake.
- Retrofit capability is high for improperly functioning dry ponds, extended detention, and when a permanent pool can be incorporated into the system.

Natural Wetlands

A wetland treatment system consists of a low-lying natural wetland area, comprised of herbaceous and/or forested wetland vegetation species. The system typically has a permanent pool of water available for pollutant removal processes.

The pollutant removal mechanisms include evaporation, sedimentation, emulsification, adsorption, filtration, precipitation, decomposition, chemical adsorption, and vegetative uptake. Generally, the removal of BOD, suspended solids, nitrogen and heavy metals is high while phosphorus removal is variable and a function of the season. The efficiencies vary substantially depending on site-specific conditions. Other characteristics of this type of treatment system include the following:

- A sediment sump is necessary at the inflow to reduce adverse impacts of sedimentation to the wetland processes.
- Nutrient retention is highly variable depending on season, sedimentation processes and vegetation.
- Heavy metal retention is also dependent on sedimentation processes, season, vegetation and pH.
- Selection of wetland for treatment of stormwater should consider normal (and proposed, if applicable) fluctuation of water levels, bathymetry of wetland, wetland species, substrate suitability, existing wetland condition/ sensitivity, stormwater volume and quality characteristics and regulatory agency constraints.

- Maintenance of the system is highly site specific but would likely include sediment removal, evaluation and minimization of ecosystem disruption and control of nuisance species, as required.
- Use in urban areas would be consistent with the retrofit options.
- Retrofit capabilities exist where impacted wetlands could benefit through revegetation and rehydration resulting from stormwater inflows.
- Additionally, habitat improvement may increase the wildlife use of the wetland and add aesthetic and recreational value.

<u>Exfiltration Trenches</u>

An exfiltration trench is a shallow excavated trench that has been backfilled with gravel to create a reservoir for promoting discharge to the ground water system. Stormwater that is diverted to the trench slowly percolates through the bottom and sides of the trench and into the subsoil.

The pollutant removal effectiveness for these systems has not been widely addressed. Available data suggests that the systems remove a high percentage of particulates and a moderate percentage of soluble pollutants. Other characteristics are as follows:

- Requires sediment sump and pretreatment grass strip to prevent sediments from clogging the system.
- Maintenance is relatively high consisting of regular removal of particulates and settled matter above trench, sediment removal and mowing.
- Potential impact to ground water from soluble constituents such as nitrates.
- Contributing drainage area should not exceed five acres.
- Not recommended for high water table locations.
- Use is limited to soils with field-verified infiltration rates greater than 0.5 inches/hour.
- Not a recommended system for catchment areas with high sediment loads and/or slopes.
- Limited use in urban areas due to disturbed soils.

- Provides good ground water recharge.

Infiltration Basins/ Percolation Ponds

Infiltration basins or percolation ponds are designed to function as dry ponds that intercept and temporarily store stormwater until it infiltrates through the pond bottom and into the subsoil.

Infiltration basins have good particulate pollutant removal capabilities and moderate removal capabilities for soluble pollutants. Pollutant removal efficiency is contingent on soil infiltration rate, depth to water table, treatment volume available per unit of watershed area and maintenance. Pollutants are removed by adsorption, straining, and microbial decomposition. Additional characteristics include the following:

- Requires sediment sump at inflow to restrict extent of sediment load.
- Requires short time period (48 to 72 hours) to infiltrate to provide storage for next storm event.
- Use is limited to areas having > three feet of depth from pond bottom to high water table.
- Use is limited to soils with field-verified infiltration rates > 0.5 inches/hour.
- Generally works well for drainage areas < 25 acres.
- Maintenance requirements are high to ensure maintenance of infiltration characteristics. Pond bottom scouring or removal and replacement of surface soils may be required.
- Provides source of ground water recharge.

Sand Filters

A sand filter is comprised of a contained bed of sand surrounding a perforated discharge pipe. The first flush of stormwater is captured, diverted to the sand bed, strained through the sand, collected in the perforated discharge pipe and conveyed to the receiving water system.

The pollutant removal efficiency for sand filters is high for particulates and trace metals and low to moderate for soluble nutrients. Pollutant removal is achieved by straining and settling. Additional characteristics include the following:

- Maintenance is high due to accumulation of particulate matter at straining surface. May require periodic removal of sand media where high sediment loads occur.
- Improved efficiency if used as off-line system.
- Pretreatment sediment sump is recommended.
- Watershed drainage area limited to < 5 acres.
- Pressure head for flow should preferably be > 2 feet.
- Commonly used in area-limited urban settings.
- Provides no wildlife habitat value.
- High water table must be below discharge pipe invert.
- Retrofit capabilities possible for instances of limited space and off-line layout possibilities.

Porous Pavement

Porous pavement is an alternative to conventional asphalt pavement surfaces that allows the infiltration of stormwater. Porous pavement is generally poured over a gravel layer or stone reservoir. Stormwater infiltrates the pavement into the gravel layers where it then exfiltrates into the surrounding soil.

Pollutant removal efficiency is good for sediment, nutrients, and trace metals. The subsoil adsorbs and strains the pollutants from the stormwater exfiltration processes. Other characteristics include the following:

- High maintenance requirement such as quarterly vacuums sweeping and/or jet hosing.
- Lack of maintenance allows clogging of pores which reduces and eventually eliminates treatment efficiency.
- Drainage areas usually < 10 acres.
- Soil must have infiltration rate > 0.5 in./hr.

- Slope should be < 5 percent.
- High water table should be > 3 feet below pavement surface.
- Traffic limits exclude large truck traffic. System commonly used on infrequently used parking areas.
- Limitations include little to no sediment inputs from adjacent lands and/or traffic.
- Use in urban areas is limited to select sites with suitable soils and acceptable land uses.
- Possible transport of toxic chemicals from asphalt and/or hydrocarbons into ground water.
- Good ground water recharge.
- Retrofit capabilities are severely limited.

Interlocking Concrete Grid Pavement

Concrete grid pavement consists of a succession of interlocking, modular, irregular shaped concrete blocks having regularly spaced voids that are filled with pervious materials. The blocks are typically placed over a filter fabric covered stabilized sand or gravel base. The grid pavement provides infiltration of stormwater while producing a stable-supporting surface for vehicular traffic. Characteristics of the grid pavement include:

- Drainage areas usually < 10 acres.
- Soil must have infiltration rate > 0.5 in./hr.
- Slope should be < 5 percent.
- High water table should be > 3 feet below pond bottom.
- Traffic limits exclude large truck traffic. System commonly used on infrequently used parking areas.
- Limitations include little to no sediment inputs from adjacent lands and/or traffic.
- Use in urban areas is limited to select sites with suitable soils and acceptable land uses.
- Good ground water recharge.

Grassed Swales

A swale is a shallow, grassed, ditch system with relatively flat slopes and low velocities. Swales are located above the water table to encourage infiltration of flow through water and are many times used in conjunction with other control methods as a means of pretreatment and water conveyance.

Swale systems have moderate success at removing particulates and trace metals. Additional treatment by settling and infiltration can be provided depending on site characteristics and can improve the removal efficiency of soluble pollutants. Other characteristics are as follows:

- Most efficient for flat slopes, wide bottoms, soils of high infiltration rates and check dams.
- Velocities should be < 1.5 feet/second.
- Requires minimal land area.
- Allows deposition and subsequent binding of pollutants to sediments and surface soils (as opposed to curb and gutter entrapment of same at curb).
- Retrofit options are limited usually due to water quantity capacity concerns.

Water Quality Inlet (Oil/Grit Separator)

A three stage underground concrete retention system designed to remove sediments and oils from stormwater.

Pollutant removal through gravitational settling and oil separation is moderate with removal credit only occurring after trapped sediments are removed from system. Other characteristics are as follows:

- Limited volume reduces efficiency.
- Use normally limited to smaller sites such as parking lots and gas stations (< 2 acres).
- High maintenance required to maintain performance.
- Disposal methods are a concern.
- No wildlife habitat benefit.

- Resuspension of pollutants during larger storm events is common.
- Retrofit capability is limited.

Off-line Retention

An off-line retention system is designed to divert a "first flush" volume out of the normal stormwater runoff conveyance system. Treatment is normally provided by infiltration. Stormwater from the later portions of the storm is presumed cleaner and is discharged directly to the receiving system.

The pollutant removal of these systems is considered high and is accomplished through infiltration, straining, and sedimentation processes. Other characteristics are as follows:

- Maintenance must be regular with sediment removal, mowing and removal of settled particulates required.
- Contributing watershed area is limited to approximately 5 acres, depending on impervious distribution.
- Use in urban areas highly dependent on land availability and soils suitability.
- Soils should have infiltration rate > 0.5 inches/hour.
- Retrofit capability dependent on land availability and water quantity requirements.

On-line Retention

An on-line retention treatment system is similar to an extended dry detention with the exception that the control structure release is elevated thereby providing an available volume of retainage that can discharge the pond via infiltration only.

On-line retention systems have moderate to high pollutant removal capabilities through sedimentation, infiltration and straining by vegetation and/or the discharge structure. Other characteristics include:

- Maintenance requirements are moderate with sediment and particulates removal, mowing, control structure maintenance regularly required

- Soils must have field verified infiltration rates in excess of 0.5 inches/hour
- Seasonal high water table should be > 3 feet below pond bottom
- Watershed area should generally be < 10 acres
- Use in urban settings depends on soil characteristics, land availability and treatment volume requirements
- Retrofit capabilities are limited and consistent with urban area characteristics

Overland Flow

Overland flow consists of a vegetated filter strip typically located adjacent to the highway. This pollutant removal technique is used to reduce velocity and promote infiltration of runoff to the subsoil. Runoff is encouraged to spread out in a wide sheet flow pattern onto adjacent vegetated land or into a vegetated swale, ditch, or pipe conveyance.

Overland flow has moderate to high removal rates of pollutants through sedimentation, vegetative filtering, and biological assimilation and infiltration mechanisms. Additional characteristics are as follows:

- Use of this method is limited by slope, soil characteristics, water table depth, type of vegetation and runoff flow characteristics (velocity and depth).
- Use in urban settings is limited due to land and traffic constraints.
- Selected vegetation should be drought tolerant, effective against erosion, compatible with soils, durable, and relatively easy to maintain.
- Generally 150-250 feet of overland flow length is necessary for adequate treatment of stormwater, depending on specific site characteristics.
- Maintenance is generally low to moderate. Increased maintenance activities may be required subsequent to larger storm events to repair erosion scours.
- Retrofit capabilities are low because of available land and traffic limitations.

## Source and Non-Structural Control Measures

Street Sweeping

Streets are collectors of a wide variety of pollutants including bits of garbage, oil, grease, heavy metals, urban wastes, fertilizers, pesticides, and others. Mechanical street sweeping is a source control method for reducing the amount of pollutants washed from the roadway via stormwater runoff. Street Sweeping involves the mechanical sweeping (broom-type) of sediments from the roadway and associated gutter. The removal efficiency of street sweeping is a function of sweeping frequency, number of passes, sediment gradation and accumulation, pollutant characterization, pavement conditions, and type of sweeper used. Overall particle removal efficiency for street sweeping is considered to be 50 percent which is comprised primarily of the larger sized particles. Unfortunately a large percentage of the pollutants are attached to the smaller particles thus lowering the actual pollutant removal efficiency of the process.

Litter Control Laws

Litter is the visible trash, such as paper, commonly found along roadsides. A large majority of litter is biodegradable and as such when in water will impose an oxygen demand as it decomposes. Litter also acts as a means of conveyance for other pollutants such as metals, fertilizer, pesticides, oils, greases, and others.

Litter-free areas encourage users of the land to maintain a clean and aesthetically pleasing environment. Elements of a complete litter control plan include:

- Comprehensive garbage collection program.
- Ordinances requiring that garbage, leaves, and other debris are properly bagged and discarded.
- Laws that prohibit littering and impose rigid fines on violators.
- Recyclable resource recovery system.

- Enforcement to ensure compliance.
- Public Education and establishment of regional clean-up programs.
- Others.

Public Education

The need for protecting the water resources of the state must be brought to the attention of all users to ensure that polluters are aware of the harm caused by their haphazard actions. The success of this source control element has the greatest bearing on the ability of non-structural control measures to reduce stormwater pollution. For it is this component (whether it be the general public or private industries) which directly impacts all other control components. Public education efforts undertaken as part of the NPDES program are discussed in detail under that section.

Traffic Flow Regulation

The deposition of pollutants on the SHS is directly related to the average travel speed of vehicular traffic. It has been demonstrated and documented by past studies that slow moving traffic deposits more pollution than does faster moving traffic. Additional incentives for efficient traffic flow include energy resource preservation, cleaner air, and subsequently improved rainfall quality.

Pesticide, Herbicide, and Fertilizer Use Control

The control of pesticides, herbicides and fertilizer involves proper training and certification in the use of equipment and rate of application. The use of pesticides, herbicides and fertilizer has a definite impact on the quality of stormwater runoff coming into contact with those substances. This control ties into the public education control because the impacts that the referenced substances have on the MS4 and waters of the U.S. are directly related to the applicator's judgement in the proper use of the materials.

Facility Inspection and Enforcement

Review of a facility for proper stormwater management (or proper implementation of the SWP3, as applicable) is a key element of any stormwater management program. The inspection program will identify the level of awareness that a given industry/facility has regarding the potential impacts its activities and materials have on the quality of stormwater discharging from the site. This component is the most important element of public education relative to businesses and industries. Follow-up compliance checks and enforcement, when needed, are very important in making the industries aware of the concerns of the MS4 operator relative to all the discharging entities within its catchment area.

Improved Maintenance

The ability of a stormwater management system to remove pollutants and treat flow through water is a function of design, construction, and maintenance of the system. As documented in numerous studies most stormwater facilities require periodic maintenance to function as intended. In addition, EPA has recognized that maintenance is critical to the attainment of a successful stormwater management program.

Recycling Program

The recycling of various materials helps to reduce the volume of trash and associated pollutants being discharged into U.S. Waters.

Illicit Discharge Elimination

The Nationwide Urban Runoff Program (NURP) study concluded that urban runoff was significantly impacted by illicit connections and illegal dumping. Often large amounts of oil and other wastes are improperly discarded within storm sewers or existing stormwater retention facilities or conveyances. Elimination of these pollutant sources through water quality screening, public education (such as storm drain stenciling), and enforcement will result in an improvement to the quality of stormwater discharging from the MS4.

To successfully implement an illicit discharge elimination program the municipalities must establish ordinances (i.e. legal authority) that prohibits the improper discharge or dumping of any waste material. The program must describe a step by step procedure to identify, investigate, and prohibit illicit discharges.

Agricultural BMPs

A variety of land management techniques are utilized in the agriculture industry to reduce the transport of sediments and chemicals to receiving water bodies. Generally these practices are focused around nitrogen, pesticide, and fertilizer load reduction and management, erosion and sediment control, and water conservation. Some of the more common practices include:

- Irrigation water management
- Mulching
- Grazing management
- Use of slow release fertilizers
- Solid and liquid waste management
- Pesticide and herbicide application management
- Tailwater recovery
- Prescribed burns
- And others

# STORMWATER BEST MANAGEMENT PRACTICES IN THE TAMPA BAY AND CENTRAL FLORIDA REGIONS

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# FOREWORD

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## 1.0 Introduction

Stormwater runoff is a potentially significant source of nutrients, i.e., nitrogen and phosphorus, as well as other pollutants, for many coastal systems. For example, stormwater runoff accounts for approximately 50% of the loadings of total nitrogen to Tampa Bay on an annual basis (Zarbock et al. 1994). Excessive inputs of nitrogen have resulted in acceleration of the eutrophication process. Management of coastal resources has in many ways focused on the problems associated with eutrophication: high algal biomass, low dissolved oxygen, increased light attenuation, etc. Ultimately, effective management of the eutrophication process depends on recognizing the sources of the nutrients in stormwater runoff and identifying methods, i.e., best management practices (BMPs), that can be employed to reduce nutrient inputs via runoff.

This technical appendix, *Stormwater Best Management Practices*, is a compilation of information obtained by an review of available peer-reviewed and grey literature sources and a series of interviews with permitting agency staff, developers, researchers, and local design engineers. The focus of the review and interviews was urban runoff. In particular, information was obtained on BMPs that are most applicable in the Tampa Bay and central Florida regions. As discussed below, information on costs, operations & maintenance, design criteria, pollutant removal efficiency, etc. were obtained for a wide variety of urban BMPs. These data will assist local planners and developers in selecting BMPs that will have the best potential for meeting State Water Policy standards, which mandate that new stormwater management systems shall be designed to achieve at least 80% reduction of the average annual load of pollutants that would cause or contribute to violations of state water quality standards, and at least 95% reduction on the average annual load of pollutants that would cause or contribute to violations of state water quality standards in Outstanding Florida Waters (Chapter 62-40.432, F.A.C.).

The data base that has been assembled also provided much of the information necessary to exercise the Tampa Bay National Estuary Program (TBNEP) BMP Optimization Model (Wade and Janicki, 1995), as presented in Appendices 1, 2, and 3. The Optimization Model was developed for the TBNEP to assist local governments in making decisions about what BMPs are most applicable and efficient in managing nutrient inputs via stormwater runoff from urbanized areas. Beyond supporting the BMP Optimization Model, this document can be used as a general reference to both urban and agricultural runoff BMPs.

It should be noted that effective management of nutrient inputs via stormwater runoff must also include nonstructural, pollution prevention BMPs such as sound site planning and design features that avoid or minimize impacts early in the urbanization process. An excellent example is the Florida Yards and Neighborhoods Program which can help to reduce the generation of stormwater pollutants, especially nutrients and pesticides, from residential yards and commercial landscaping. Stormwater runoff-related impacts typically result from reduction in the ability of an area to infiltrate or otherwise attenuate stormwater inputs. Thus, plans that minimize disruption of the basic hydrology of the area to be developed are clearly desirable. Local government land use planning ordinances should minimize imperviousness and require the evaluation of such options as can be used to address the issues associated with stormwater runoff.

In addition to information on urban BMPs, we have also assembled pertinent information on agricultural BMPs for the Tampa Bay and central Florida regions. Interviews with local agricultural extension service staff and literature searches were completed to identify and obtain this information.

## 2.0 Urban BMPs

Most activities that occur in conjunction with the construction, operation, and use of urban land have the potential for introducing pollutants to surface water through stormwater runoff. Construction activities, operation of motor vehicles, landscape maintenance, and industrial activities all have the potential to increase pollutant loadings from runoff. In addition, rainfall falling on buildings, roads and parking lots, and other impervious surfaces often produces in runoff that carries some polluting substance to a receiving water body.

A wide variety of BMPs is available to control stormwater quantity and quality impacts to the environment. BMPs may be based on facilities such as ponds, storm drains, or other constructed facilities. These BMPs are typically classified as structural BMPs. BMPs also include management practices that do not depend on built structures. These BMPs are typically classified as non-structural BMPs. Non-structural BMPs involve activities such as public education regarding appropriate use of landscape chemicals, development standards that preserve natural vegetation, or the use of alternative biological pest controls in place of chemical pesticides.

The following descriptions of the urban BMPs are based on the reviews of many documents. The primary references include USEPA (1993), Schueler et al. (1992), Livingston et al. (1993), NVPDC (1980), Schueler (1987), Dillaha et el. (1987), Lowrance et al. (1985), Natter and Gaskin (1989), and USDA-Soil Conservation Service (now the Natural Resources Conservation Service) (1988). These descriptions provide a basic framework for understanding other BMPs which are typically variants of the categories listed below.

In addition to the literature reviews we contacted and interviewed a number of people closely involved with the stormwater issues. Table 1.2 presents a list of those people. The questions asked in these interviews focused on their recent experiences in the application of BMPs.

Telephone interviews were conducted to obtain information regarding the frequency of use in Florida, and the reasons for use, of different urban stormwater BMPs. A cross-section of regulators (permitting and enforcement), developers (homebuilders and site development engineers), and researchers (academic and government agency) were called to record experiences and professional opinions of individuals with experience in the design, permitting, construction, monitoring, and maintenance of BMPs. A series of questions regarding BMP practices was asked of the contacted individuals. The text below summarizes responses that were received. The following Table 1.2 lists all those who were contacted to discuss BMPs.

1) What stormwater BMPs are most commonly used in your project/permit applications?

By far the most common urban stormwater quantity and quality BMPs used or permitted by those contacted were on-site depressional facilities such as ponds or low-lying open spaces. Common design alternatives included wet detention, percolation ponds, and sand filtration. Other alternatives were generally used only under special circumstances (little available land, physical site constraints, etc.). The decision to use wet or dry ponds appears frequently to be driven by site constraints. If a site has good infiltration features, dry ponds are used. If a high water table exists or soils have a low percolation capacity, wet ponds are more common.

In cases where the less common BMP alternatives were used, they often appear in series, as a "treatment train" (e.g., swale with filter inlet discharging to an exfiltration trench). This may be necessitated by the generally lower capacity of many alternative BMPs. Regulators perceived a preference of applicants for wet detention ponds for residential development, and dry detention, swales, and exfiltration for commercial. This was thought to be a function of lower land availability (or higher land cost/square foot) on commercial sites.

| Table 1.2 Individuals contacted for interviews for urban stormwater BMPs. | |
|---|---|
| Richard Alt | SWFWMD MSSW Engineer |
| William Copeland | SWFWMD MSSW Biologist |
| Alba Evans | SWFWMD MSSW Enforcement |
| Betty Rushton | SWFWMD Resource Projects |
| Hank Higgenbotham | SWFWMD Resource Permits Technical Staff |
| Betty Barton | USEPA Region IV Nonpoint Source |
| Jeannie McNeill | USEPA Region IV Stormwater NPDES |
| Eric Livingston | FDEP Surface Water |
| Martin Wanielista | University of Central Florida |
| Carlos DeRojas | SFWMD MSSW permitting |
| Jeff Needles | SWFWMD - IRLNEP research |
| Allen Baggett | SJRWMD MSSW Engineer |
| J.P. Marchon | Sarasota County Stormwater Utility |
| Paul Dewey | Pinellas County Stormwater Permitting |
| Elie Araj | Hillsborough County Engineering Services |
| Lynn Johnson | City of Orlando Street and Drainage Dept. |
| Michael Burwell | City of Tampa Stormwater Planner |
| William Chamberlin | City of Orlando Stormwater Utility |
| Rod Lynn | Orange County Stormwater Management |
| Jeff Spence | Polk County Water Resources |
| Curtis Watkins | City of Tallahassee Stormwater Management |
| Matt Forbes | Disney Development Corporation |
| Mahmound Elsabaugh | Reedy Creek Improvement District |
| William Walwick | Sarasota County Homebuilders |
| Rodney Fischer | Pinellas County Homebuilders |
| Brenda Kunkel | Hillsborough County Homebuilders |
| Keith Tracey | Florida Association of Homebuilders |
| Richard Harris | Cumbey & Fair Engineers |
| Tyler Johnson | Westchase Development |

2) Which are the most difficult/easiest to construct?

Applicants and regulators agree that the more common BMPs (wet and dry ponds) are easiest to construct. Both the logistical aspects of construction, cost, the need to remain in conformance with permit design criteria, and the ability to meet performance standards, are factors that affect construction degree of difficulty. Swales were intermediate in construction difficulty. BMPs that were said to be hardest to construct include sand filters, exfiltration trenches, and porous pavement, mainly because the specifications for proper construction are more demanding than those for ponds, and because the site conditions that necessitated the alternative BMP use are often unfavorable for standard construction techniques.

3) Which are the most difficult/easiest to permit? Are any mandatory?

Obtaining permits (regulatory acceptance) was said to be easiest for wet and dry ponds. No BMP type is mandatory, but site constraints often dictate that one of a few alternatives be selected. Many BMPs alternatives were perceived to be harder to permit, but were most easily permittable under special conditions. The relative difference in permitting ease is based on such factors as regulatory familiarity, existence of feasible design standards and achievable performance standards, past performance, and the relative need for enforcement actions of previously permitted projects.

4) What are typical construction costs per acre or per acre of drainage area?

Construction costs for BMPs vary greatly, depending on the BMP type and land cost. Land cost is often the single greatest expense in BMP development. Wet or dry detention ponds with no enhancements (underdrains, special inlets, exfiltration system, etc. typically cost $25,000 to $35,000 per acre of pond, depending on the site characteristics. Constructed wetlands are somewhat more expensive on a per-acre basis. Water quality inlets can cost between $5000 to $8000 each, infiltration trenches may cost approximately $7000 to $8000 per acre of area treated, while seeding and mulching totals approximately $1000 to $2000/acre. Within the region, costs were relatively similar for the same BMPs.

5) What are typical Operating&Maintenance (O&M) costs?

O&M for a stormwater facility may include a wide range of activities, including landscaping, inspection and upkeep of control structures, cleaning inlets and outlets, sediment removal, repairing erosion, etc. Annual O&M costs were found to vary from 2-5% of construction costs for most types of ponds (lower for dry ponds, higher for wet ponds), to 5-10% of construction costs for the more maintenance-intensive BMPs such as exfiltration systems or porous pavement.

6) Is an O&M manual needed for maintenance crews?

In many cases no O&M manual is supplied. However, the District does have a checklist of recommended maintenance procedures, and some site development engineers routinely provide maintenance manuals for drainage facilities, particularly for commercial sites. Also, the District requires a periodic report (signed and sealed by the Engineer of Record) for permitted facilities that attest to the continued maintenance and proper functioning of stormwater ponds and other BMPs.

7) What BMPs do you anticipate using/would you rather use in the future?

Those interviewed did not foresee any drastic changes in BMP selection in the immediate future. Wet and dry detention ponds, infiltration basins, swales, and other now-common BMPs were seen as most likely to be used in the future.

## 2.1 Structural BMPs

As stated above, structural BMPs can include any management practice that is based on a constructed facility, including ponds, swales, control structures, pipes, etc. These BMP alternatives may utilize a variety of processes, including "end of pipe" treatment, overland flow routing, physical or chemical treatment, recycling, wetland systems with biological treatment, or infiltration.

Structural BMPs can be very versatile. They may be planned and designed as an integral part of the site development process, or they may be added after development has occurred, which typically is referred to as a retrofit application. Although the most flexibility in BMP selection occurs during the site planning and design stage, many BMPs are feasible for use in a retrofit situation. These often include alternatives with minimal land requirements, such as underground vaults, water quality inlets, or swales.

BMPs may be used individually, or in series. Using sequential BMPs (for example, a grassed swale discharging through a structure with a skimmer to a detention pond with underdrains) increases the net treatment effectiveness and usually results in a higher percent removal of pollutants from the stormwater. The practice of combining several BMPs in series is often called a "treatment train."

Structural BMPs may also be classified as "on-line" or "off-line." The entire flow of stormwater is channeled through an on-line BMP, while an off-line BMP receives only a fraction of the total flow. Off-line BMPs can be designed to capture the first volume of stormwater ( the "first flush"), which often carries proportionally higher pollutant loads than the later flows.

The following introduces some of the more common categories of structural BMPs. Because many BMPs serve multiple purposes, their categorization is mainly a matter of convenience, and distinct separations in function are often not identifiable. Therefore, a BMP may be appropriate to list in more than one category.

- Runoff Control Practices

  Runoff control practices are designed to manage stormwater runoff in a manner that minimizes its negative impacts on the environment. This may be accomplished by the use of diversion berms, swales, overall site grading, detention or retention storage of stormwater, biological treatment, or infiltration.

- Erosion Control Practices

  Erosion control practices are intended specifically to minimize soil loss and erosion from a site, which serves two purposes. By reducing erosion physical damage to property, such as a construction site with exposed soil, is reduced. Also, erosion results in soil particles becoming entrained in runoff. This pollutant load of suspended solid material can cause environmental damage by covering desirable benthic habitats, smothering aquatic vegetation, or by carrying other pollutants such as metals or organic compounds that have become attached to the soil particles.

  Erosion control can be accomplished by structurally oriented means such as site grading (terracing and contouring), use of runoff control methods described above to contain runoff on-site, or by the stabilization of exposed soil using rip rap or gravel. Vegetation can also be used to stabilize soil areas through the use of vegetated buffers, grass, mulch, ground covers, preservation of trees, etc.

## 2.2 Nonstructural BMPs

Nonstructural stormwater BMPs are as diverse as structural options. Numerous alternatives for managing stormwater are available that do not depend on physical structures. As with structural BMPs, nonstructural BMPs may be included in more than one category. In addition, the issue of public education could be a separate class of nonstructural BMPs, but is really a factor in each of the listed categories. The following general categories include many of the nonstructural alternatives that are discussed separately below.

- Good Housekeeping

Good housekeeping includes general maintenance and policing activities that reduce the amount of debris, litter, and garbage available for contact with stormwater. If implemented on a wide scale, these activities can be very effective, as well as relatively inexpensive. Examples of good housekeeping include general surface sanitation - anti-litter measures, streetsweeping (wet or dry, with vacuum or brush), cleaning drainage inlets of debris, controlling air pollution from both mobile and stationary sources, cleaning debris from constructions sites daily, and good solid waste collection and disposal methods. Good housekeeping is a BMP that can be implemented by governmental agencies and/or commercial entities (construction companies, private citizens, public interest groups, etc.). Good housekeeping efforts can often be enhanced through public education and changing old habits regarding waste disposal and treatment of the land. Adopt-a-Road and Adopt-a-Pond programs are examples of good housekeeping projects that can ameliorate stormwater pollutant loading.

- Source Control

Source control is a broad category of BMP activities that addresses stormwater pollution at the true source of pollutant inputs. Traditional BMPs act to reduce the pollutant load after runoff has become contaminated. Source controls attempt to reduce the initial distribution of pollutants to the environment. Source control practices can apply to changing the rate of fertilizer application or using natural fertilizer and pesticide products; storage, use and release of industrial chemicals; etc. As with structural BMPs, there is a certain degree of overlap in the categorization of nonstructural BMPs. For example, one important aspect of source control is good housekeeping.

Another important aspect of source control is to ensure that users of chemicals and any material that could contaminate runoff know the proper application rates, methods, and timing for their uses. This can be accomplished through packaging, public interest groups, private interest groups, local government programs (i.e., Extension Service), etc.

## 2.3 Potential Criteria for Use in the Selection of Effective Urban BMPs

The purpose of BMPs is to reduce pollution loads and, in some cases, peak runoff. Two main criteria for establishing the effectiveness of BMPs are, therefore, the effectiveness of pollutant removal and peak flow reduction. There are specific pollutants of interest in stormwater and these pollutants are treated with different degrees of effectiveness.

The primary nutrients that generally control phytoplankton growth are nitrogen and phosphorous. Previous research has shown Tampa Bay to be nitrogen-limited. Therefore, nitrogen control is of primary importance. However, since phosphorus is the other primary nutrient, phosphorus control is also important. Total suspended solids and the associated trace metal (cadmium, lead, chromium, etc.), organic (PCBs, polyaromatic hydrocarbons (PAHs)), and biological (bacteria, viruses) pollutants also can significantly impact Tampa Bay biota. Consequently, the stormwater pollutants of interest have been identified as total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS).

To compare the effectiveness of specific BMPs, the degree of pollutant removal is typically rated in terms of "efficiencies". For example, a 90% nitrogen removal efficiency means that the BMP reduces the nitrogen concentration of water leaving the BMP by 90%, relative to the concentration of stormwater flowing into the system. Based on the above, the effectiveness of BMPs for the Tampa Bay watershed can be established as the efficiencies of removing nitrogen, phosphorus, and total suspended solids from stormwater. There is, however, other critical information that is important in comparing the effectiveness of BMPs. Included are area treated, design storm peak discharge control, depth to water table, site slope, construction and O&M cost, land use, soil characteristics, amount of land used, life span, and other constraints such as adverse social impacts. The criteria can be grouped into four categories: benefits, costs, constraints, and potential advantages/ disadvantages.

**BENEFITS**

**Total Nitrogen Removal Efficiency** — The proportion of the total nitrogen (TN) load entering a BMP that is removed by that BMP.

**Total Phosphorus Removal Efficiency** — The proportion of the total phosphorus (TP) load entering a BMP that is removed by that BMP.

**Total Suspended Solids Removal Efficiency** — The proportion of the total suspended solids (TSS) load entering a BMP that is removed by that BMP.

**Peak Discharge Control** — The ability of the BMP to attenuate maximum stormwater runoff rates for specific return period storms.

COSTS

**Construction Cost** — A major criterion affecting the selection and implementation of specific BMPs. Construction cost is often expressed as a unit cost (e.g., $/pound of TN removed).

**Operation & Maintenance Cost** — A potentially major criterion affecting the selection and implementation of specific BMPs, such as infiltration trenches and water quality inlets. O&M cost is often expressed as an annual cost ($/year).

**Amount of Land Used** — This will determine the cost of the land and consequently the cost of the BMP implementation.

**Life Span** — The life span is also related to the overall cost. Projects with long life spans are usually more economically beneficial than those with short life spans.

**CONSTRAINTS**

| | |
|---|---|
| **Area Treated** | The area of the watershed that provides stormwater inflow to the BMP. It is assumed that the channel(s) convey all water generated on the watershed to the stormwater treatment system. |
| **Depth to Water Table** | An indicator of the depth of soil available for infiltration systems. It also provides information for designing wet detention systems. |
| **Slope** | Slope is an important constraint for construction purposes as it may limit the type of BMP that may be constructed. |
| **Soil Characteristics** | Important factors for BMP construction. Each BMP requires specific soil characteristics for efficient operation of the BMP. |
| **Land Use Type** | A major constraint for the implementation of specific BMPs since some BMPs are not universally applicable to all land use and land cover types. |
| **Peak Discharge** | The maximum stormwater runoff flow rate during a rainfall event is often a limiting factor in the design of a BMP. |

ADVANTAGES/DISADVANTAGES

| | |
|---|---|
| **Adverse Environmental Impacts** | Potential adverse impacts such as groundwater contamination by infiltration trenches and loss of upstream habitat by wet pond construction. |
| **Adverse Social Impacts** | Potential adverse impacts such as loss of property or aesthetic value, potential nuisance conditions such as mosquito breeding. |
| **Augmentation of Groundwater Recharge** | The increase in infiltration of stormwater into the groundwater table. |
| **Waterfowl, Fish, and Wildlife Habitat** | The added benefit afforded by some BMPs by providing new and often valuable habitat. |

The following is a presentation of the more commonly used BMPs, with summaries of relative feasibility in terms of permitting, construction cost, maintenance requirements, and effectiveness. Many less widely used, but none the less significant BMPs, are also summarized. The information presented below is intended to assist in the process of selecting stormwater BMPs that would be feasible under specific circumstances. Location, land use, land cost, required treatment levels, and other factors may mandate the use of certain BMPs and make the use of others infeasible. Each BMP is described below under the following sub-headings

Description and Function: This section describes the form and function of the BMP. The overall feasibility, purpose, and operating principal of the BMP is explained in this section.

Design Guidelines: This section lists specific design criteria and considerations for the effective operation of the BMP. For example, travel time through a swale or pond, or area to depth ratios are discussed.

Related facilities. Similar facilities, or BMPs that work well in concert with the subject BMP are listed in this section.

Regulatory Considerations: Ease of permitting, frequency of use, and acceptability to regulators is discussed in this section.

Overall Advantages and Disadvantages: The overall feasibility, the BMP's major strong points and weaknesses are listed in this section.

Site Constraints: Land requirements for the effective functioning of the BMP, in terms of site size, maximum feasible size, site slope, soil infiltration rates, and water table depth are listed in this section.

Operational Efficiencies: Ranges of TN, TP, and TSS removal as documented in the literature are given in this section.

O&M Requirements: Types and frequencies of O&M activities are listed in this section.

Cost: Ranges of construction, and O&M costs are given, either on a unit cost, total cost, or annual cost basis.

## EXTENDED DRY DETENTION BASIN

**Description and Function:**

Extended detention dry basins are impoundments in which stormwater runoff is temporarily stored until it gradually leaves the basin through an outflow control structure. The control structure is designed to allow a gradual bleed-down of the collected surface water to receiving waters. This produces the benefits of attenuated peak flood flow rates and reduced risk of downstream flooding caused by development. Some reduction in surface flows may also occur through infiltration, evaporation, and transpiration, although these are not the primary mechanisms of release from the impoundment. As a result, peak flood flow rates are kept low through the use of detention basins, but the overall flood volume is virtually unchanged. Extended detention dry ponds are, as the name implies, to be designed so that no standing water remains in the basin after the bleed-down period.

Water quality benefits are also realized primarily through settling, or sedimentation, of particulate matter that may contain metals and organic contaminants, especially larger, heavier particles. Treatment is also afforded, though to a lesser degree, through the biological cycling of nutrients. In addition, runoff that infiltrates to the surficial aquifer receives water quality treatment through bacterial action and straining through the soil particles. Dry basins can also be incorporated into multi-use facilities, and serve as playgrounds, parks, recreation areas, or upland habitat during dry periods.

Dry detention basins are used most effectively in areas with a moderately deep water table (several feet below the bottom of the basin). Although it is not necessary to obtain significant infiltration rates at a dry detention basin site, the basin bottom should remain unsaturated when not holding stormwater, so as to maintain aerobic bacteria. Also contributing to the effective functioning of dry detention basins is a design that allows sufficient retention time to allow settling of particulate material and some biological uptake. Dry detention basins are not commonly permitted for stormwater treatment in west-central Florida. They have been shown to frequently not meet water quality treatment standards established by the Florida State Water Policy, and require frequent maintenance to remove accumulated sediment to prevent resuspension and discharge. The South Florida Water Management District (SFWMD) does permit the use of these BMPs, and the St. Johns River Water Management District (SJRWMD) considers extended dry detention basins to be an experimental BMP for use only on small sites with very specific design criteria.

**Design Guidelines:**

Performance generally benefits from design features to prevent short circuiting, e.g.: two or more distinct cells to promote plug flow; preferred effective length-to-width ratio 5:1, minimally 2:1; inlet and outlet either located far apart or shielded by baffling; low inlet velocity; uniform flow distribution across the inlet pond; and discharge of water with minimum turbulence from mid-depth via bleed-down from the outlet structure, located at the lowest part of the site. The removal capabilities of plants may be incorporated by managing part of the basin as a shallow wetland. Side slopes should be grassed. Side slope grades of no shallower than 8 horizontal to 1 vertical (8:1) are preferred, 4:1 side slopes are common, and 2:1 grades are the steepest allowed, but only on fenced sites. SJRWMD design criteria include providing off-line detention for the first one inch of runoff or the first 2.5 inches of runoff from impervious surfaces, which ever is greater, with additional treatment for discharge to protected Waters of the State. Additional design criteria address facility construction to prevent the discharge of accumulated sediments and the potential for clogging, to ensure adequate maintenance, and to direct the flow of stormwater evenly and with minimal turbulence through the system.

References 13, 19, 35, 36

## EXTENDED DRY DETENTION BASIN

**Related Facilities:**

Inlet structures; overflow outfall with erosion control

**Regulatory Considerations:**

Dry detention basins are not commonly permitted for stormwater treatment in west-central Florida. They have been shown to frequently not meet water quality treatment standards established by the Florida State Water Policy, and require frequent maintenance to remove accumulated sediment to prevent resuspension and discharge. The South Florida Water Management District (SFWMD) does permit the use of these BMPs, and the St. Johns River Water Management District (SJRWMD) considers extended dry detention basins to be an experimental BMP for use only on small sites with very specific design criteria.

**Overall Advantages/Disadvantages:**

Advantages: Extended detention dry basins are somewhat effective for capturing solids or other contaminants connected with particulates, given adequate maintenance. This BMP has relatively low construction cost, and can be incorporated into passive recreational use.

Disadvantages: Removal efficiencies are typically half of that obtained using wet ponds. The site must have adequate depth to the water table and permeable soils for infiltration. Frequent maintenance is required to remove accumulated sediment to prevent resuspension and discharge. Land requirements may be up to 12% of commercial sites.

References 10, 13, 45

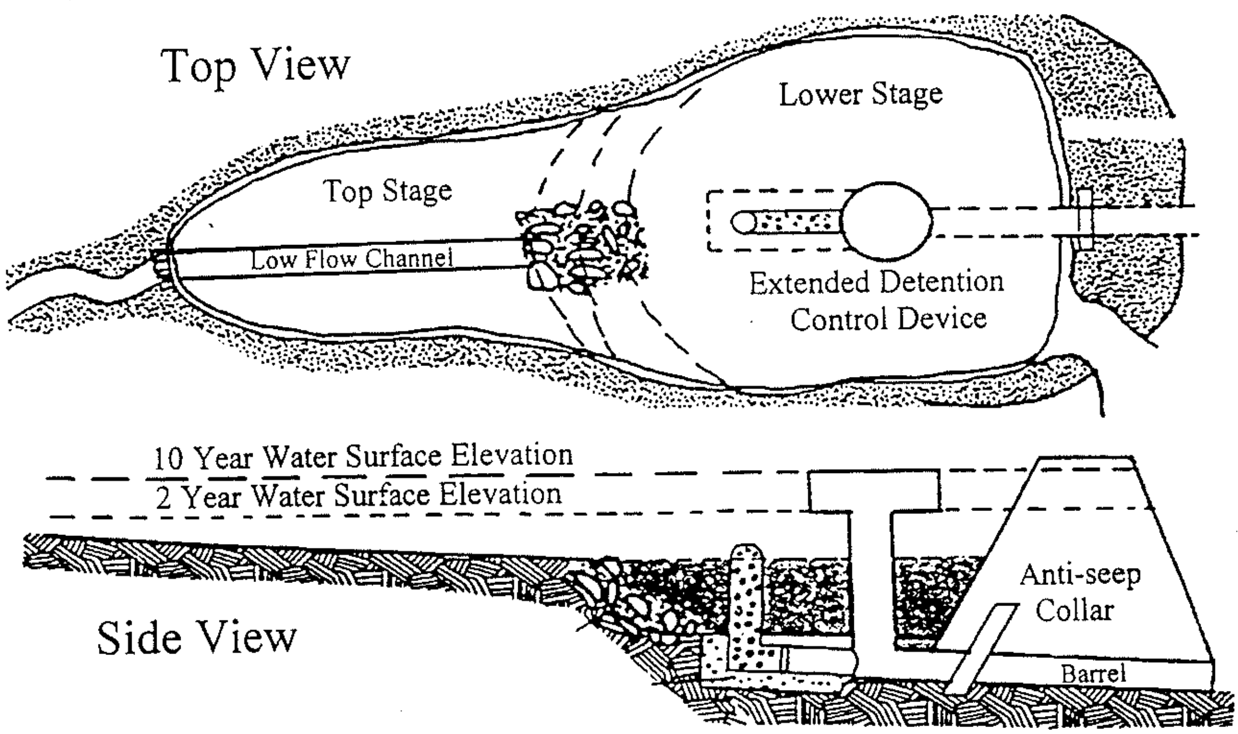
| Site Constraints: | | References |
|---|---|---|
| Treated Area: | 1) At least 10 acres | 33 |
| | 2) 15 - 100 acres | 13 |
| | 3) 22.5 - 100 acres | 37 |
| | 4) 5 acres or less | 36 |
| BMP Area: | 1) Less than 5% of total drainage area: 0.50 acre | 30 |
| | 2) Up to 12% of site | 10 |
| Depth to Water Table: | 1) Minimum=2 feet | 33 |
| | 2) Minimum=1 foot to seasonal high groundwater | 36 |
| Site Slope: | 1) Range=3%-20%; slopes greater than 29% should be stabilized with riprap | 30 |
| | 2) Less than 5% | 14 |
| Soil Permeability: | 0.05 in/hr (sandy clay) to 8.27 in/hr (sand) | 30 |

## EXTENDED DRY DETENTION BASIN

| | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=20%-60% | 41 |
| | 2) Mean=25%, Maximum=52% | 30 |
| | 3) Range=0%-30% improvement in water quality | 16 |
| | 4) Range=0%-20% for 40 hr detention | 13 |
| | 5) Range=20%-40% for first-flush detained 6-12 | 30 |
| | hrs; | 21 |
| | 6) Range=20% - 60%; Mean=30% | |
| TP Removal: | | 41 |
| | 1) Range=10% - 55% | 33 |
| | 2) Range=10% - 30% | 30 |
| | 3) Range=15% - 70% | 16 |
| | 4) Range=0% - 30% improvement in water quality | 13 |
| | 5) Range=10% - 20% for 40 hr detention | 30 |
| | 6) Range=20% - 40% first-flush detained 6-12 hours | |
| | 7) Range=40% - 60% for runoff from 1 inch | 30 |
| | detained 24 hrs; 60% - 80% for runoff from 1 inch | |
| | detained 24 hrs with shallow marsh in bottom stage | |
| | 8) Range=10%-55%; Mean=25% | 30 |
| TSS Removal: | 1) Range=5%-90% | 41 |
| | 2) Range=30%-70% | 33 |
| | 3) Mean=65% | 30 |
| | 4) Range=0%-30% improvement in water quality | 16 |
| | 5) Range=50%-70% for 40 hr detention | 13 |
| | 6) 85% | 18 |
| | 7) Range=60%-80% for first-flush detained 6-12 hrs | 30 |
| | 8) Range=80%-100% for runoff from 1 inch | 30 |
| | detained 24 hrs; | |
| | 9) Range=5%-90%; Mean=45% | 21 |
| Flood Attenuation Capacity: | 1) 25-year 24-hour storm | 35 |
| | 2) 100-year | 13 |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, erosion control at inlet, sediment removal, outfall structure maintenance | |
| Relative Level of O&M Required: | Moderate to high | |
| Maintenance Period: | A minimum of 6 times annually | |

| EXTENDED DRY DETENTION BASIN | | | |
|---|---|---|---|
| **Costs:** | | | |
| | Construction: | 1) $2,510/acre treated | 6 |
| | | 2) $0.50/ft³ of runoff treated | 14 |
| | | 3) Cost = $10.71V_s^{0.69}$ in 1985 dollars, plus 25% for miscellaneous costs, where $V_s$ is detention volume. | 30 |
| | Operations & Maintenance: | 1) 3-5% of construction cost annually: $100 per treated acre, or about $300 - $500 per maintained acre, which is the pond and buffer, or about 3 times the surface area of the pond. | 30 |

# Extended Detention Dry Basin Schematic




Adapted from: Schueler (1987)

## WET POND

**Description and Function:**

Wet ponds (extended detention wet basins) are impoundments in which stormwater runoff is temporarily stored until it gradually leaves the basin through an outflow control structure. The control structure is designed to gradually bleed-down the collected surface water. This produces the benefit of attenuating peak flood flow rates and reducing the risk of downstream flooding. Some reduction in surface flows also occurs through infiltration, evaporation, and transpiration. Therefore, peak flood flow rates are kept low through the use of wet ponds, but the overall flood volume is virtually unchanged. Wet ponds are, as the name implies, to be designed so that a pool of standing water remains in the basin after the bleed-down period. This permanent pool can be used to support emergent vegetation, which can enhance pollutant removal from the stormwater. Water quality benefits are also realized through settling of particulate matter that may carry metals and organic contaminants, and through the biological cycling of nutrients. In addition, runoff that infiltrates to the surficial aquifer receives water quality treatment through bacterial action and straining through the soil particles, although infiltration is not a significant factor in wet pond functioning. The treatment efficiency of wet ponds is largely a function of residence time of stormwater in the pond. As a result, wet ponds are generally more effective at removing many pollutants than dry retention ponds. Wet ponds can also be incorporated into multi-use facilities, providing aesthetic, recreational, and habitat benefits.

Wet ponds are most effective in areas with a water table that is far enough below the land surface to allow several feet of storage capacity within the pond at all times, but not below the pond bottom. This promotes the survival of wetland vegetation during periods of no rain. Effective functioning of wet ponds depends on designs that allow sufficient residence time (up to 72 hours) to allow settling of particulate material and some biological uptake. The use of wet ponds is very common in Florida. The relatively low cost of construction, ease of maintenance, site water table characteristics, and extended growing season make this an attractive method of stormwater control. In addition, wet ponds are frequently incorporated into development site designs as open water body amenities, and can serve a secondary function of providing fill material for building foundations and road beds. Because of their frequency of use and overall effectiveness, wet ponds are popular with regulators and are relatively easy to obtain permits for, given an appropriate design and site.

## WET POND

**Design Guidelines:**

Large surface area-to-volume ratio shortens solids settling distance, and allows better aeration and light penetration enhancing pollutant loading biological mechanisms. Other features which reduce the tendency of inflow water to "short circuit" include: two or more distinct cells to promote plug flow; preferred effective length-to-width ratio 5:1, minimally 3:1; inlet and outlet either located far apart or shielded by baffling; low inlet velocity; uniform flow distribution across the inlet pond cross section; and discharge of water with minimum turbulence from mid-depth. Side slopes above seasonal high water of 4:1, or 2:1 with site fencing, are preferred. A littoral shelf with a slope of 3% - 6% should be incorporated. The pond should be designed for a 14-day residence time, with at least 35% of the surface area in littoral zone planted with appropriate aquatic vegetation. The outfall structure should provide for gradual release of the treatment volume over a 120-hour (five-day) period. Sediment traps or forebays should be located at all inlets. Safety features include an emergency overflow weir stabilized to avoid erosion and possible failure during high flow; a shallow safety bench at least 10 feet wide at the toe of the slope surrounding the perimeter; a vegetative buffer and fencing to keep children away from the pond; and an outlet structure placed out of reach of children.

References 13, 16, 19, 35

**Related Facilities:**

Inlet structures; Control structures for outfall

**Regulatory Considerations:**

This BMP is widely and frequently used, and is generally acceptable given appropriate site characteristics. In the SWFWMD wet ponds are required to treat the first one inch of runoff, rather than the runoff from the first one inch of rainfall required for other stormwater treatment options.

**Overall Advantages/Disadvantages:**

Advantages: Wet ponds offer greater treatment advantages than ponds that dry out between storms. Maintenance and construction costs are relatively low, and this BMP is acceptable to regulators. Wet ponds can be used in areas with a high water table, and can be considered multi-use facilities, providing habitat and recreational opportunities.

Disadvantages: Maintenance level is lower than for dry ponds because of the reduced need for sediment removal. However, vegetation control and harvesting is necessary. Wet ponds provide limited storage in areas with high water table levels, and safety and aesthetic problems can arise if the pond is not appropriately maintained. Land requirements can be a factor determining the use of this BMP.

Reference 13

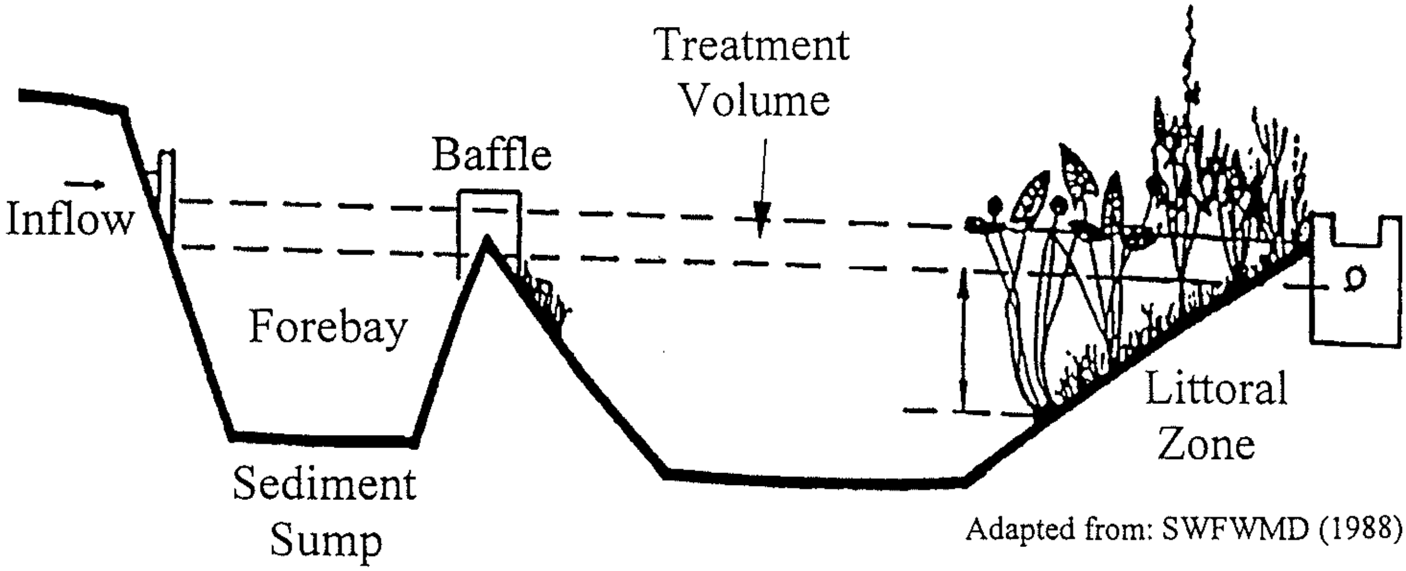
| WET POND | | |
|---|---|---|
| **Site Constraints:** | | |
| Treated Area: | 1) Range=10-640 acres | 33 |
| | 2) Range=10-100 acres | 13 |
| | 3) Range=20-100 acres | 37 |
| | 4) Minimum=10 acres | 13, 30 |
| | 5) Range=15-100 acres | 11 |
| | 6) Minimum=8 acres | 16 |
| BMP Area: | 1) Range=1-3% of total drainage area | 33 |
| | 2) 1 acre-foot per 4 acres of treated area | 30 |
| | 3) Minimum=5% of treated area | 16 |
| | 4) Range=3-7% of treated area | 13 |
| | 5) Up to 12% of a commercial site | 10 |
| Depth to Water Table: | None specified | |
| Site Slope: | 1) Range=3-20% | 30 |
| | 2) Less than 5% | 14 |
| | 3) Littoral shelf slope of 10:1 or less out to 2-3 feet below normal water level, then no more than 6:1. | 16 |
| | 4) Side slopes less than 20% | 13 |
| Soil Permeability: | Less than 0.02 in/hr (clay) to 1.0 in/hr (sandy loam) | 47 |

## WET POND

| | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=40-80% | 33 |
| | 2) Mean=30% | 28 |
| | 3) Mean $NO_3$=60%; Range TN: 0%-45% | 30 |
| | 4) 80% or greater | 16 |
| | 5) Range=20-40% with permanent pool equal to 0.5 inch storage per impervious acre; and for permanent pool equal to 2.5(Vr), Vr is mean storm runoff | 30 |
| | 6) Range=40-60% with permanent pool equal to 4.0(Vr), or approximately 2 weeks retention | 30 |
| | 7) Range=5-85%; Mean=35% | 21 |
| | 1) Range=30-90% | |
| TP Removal: | 2) Mean=54% | 33 |
| | 3) Mean OrthoP=80%; Range=TP 30-90% | 28 |
| | 4) 80% or greater | 30 |
| | 5) Range=40%-60% with permanent pool equal to | 16 |
| | 0.5 inch storage per impervious acre; and for | 30 |
| | permanent pool equal to 2.5(Vr), Vr is mean storm runoff | |
| | 6) Range=60%-80% with permanent pool equal to | 30 |
| | 4.0(Vr), or approximately 2 weeks retention | |
| | 7) Range=10%-85%; Mean=45% | 21 |
| TSS Removal: | | 33 |
| | 1) Range=30%-90% | 28 |
| | 2) Mean=61% | 30 |
| | 3) Range=0%-98%; Mean=54% | 45 |
| | 4) Range=40%-90% | 30 |
| | 5) Range=60%-80% with permanent pool equal to 0.5 inch storage per impervious acre; and for | |
| | permanent pool equal to 2.5(Vr), Vr is mean storm runoff | 30 |
| | 6) Range=80%-100% with permanent pool equal to | 21 |
| Flood Attenuation Capacity: | 4.0(Vr), or approximately 2 weeks retention | |
| | 7) Range=30%-91%; Mean=60% | 35 |
| | 25-year 24-hour storm | |

| WET POND | | |
|---|---|---|
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, aquatic vegetation harvesting, outfall structure maintenance | 10 |
| Relative Level of O&M Required: | Lower than dry pond | 10 |
| Maintenance Period: | 2 times annually | 10 |
| **Costs:** | | |
| Construction: | 1) \$2,800/acre treated | 6 |
| | 2) For volumes less than 10,000 $ft^3$, Cost=$6.1V_s^{0.75}$ | 14, 30 |
| | 3) For volumes greater than 10,000 $ft^3$, Cost=$34V_s^{0.64}$ | 30 |
| Operations & Maintenance: | 1) 3-5% of construction cost annually: \$112 per acre treated | 33, 30 |
| | 2) \$300 - \$500 per maintained acre, which is the pond and buffer, or about 3 times the surface area of the pond | 30 |

# Wet Pond Schematic




Adapted from: SWFWMD (1988)

## CONSTRUCTED WETLANDS

**Description and Function:**

Constructed wetlands serve primarily to provide water quality treatment to stormwater runoff that has been directed into a detention area. Water quality benefits are realized through physical (settling and entrapment of particulate material) and biological (plant uptake of nutrients) processes. Pollutants subject to these mechanisms are subsequently removed, at least temporarily, from the stormwater when it is released from the treatment system. If emergent vegetation is not harvested and is allowed to decay in the system, or if accumulated sediments potentially rich in nutrients and toxic contaminants are not periodically removed but allowed to accumulate, detritus and resuspended sediments may be flushed from the treatment areas during periods of high flow, thus re-introducing these pollutants into surface waters. Constructed wetlands can also be incorporated into multi-use facilities, providing aesthetic, recreational, and habitat benefits.

Treatment wetlands are typically constructed as an integral part of a wet detention system. Biological treatment littoral zones in wet detention ponds are planted with a wide variety of native and desirable aquatic vegetation and are maintained to prevent invasion by cattails or other nuisance species.

Constructed wetlands are most effective in areas with a water table that is shallow enough to sustain the wetland vegetation during periods of no rain. However, the water table must be far enough below the land surface to allow several feet of storage capacity at all times within associated flood attenuation ponds. Designs that allow sufficient retention time (up to 72 hours) to allow particulate material to settle and to promote biological uptake of nutrients also enhance the functioning of constructed wetlands.

The use of constructed wetlands is very common in Florida. Water table characteristics, the extended growing season, and overall effectiveness in pollutant removal make this an attractive method of stormwater control. Because of their frequency of use, overall effectiveness, and benefits to habitat, constructed wetlands are popular with regulators and are relatively easy to obtain permits for, given appropriate design and site characteristics.

## CONSTRUCTED WETLANDS

**Design Guidelines:**

A runoff quantity control device should be placed on-line and a constructed wetland should be placed off-line to treat all runoff up to a certain volume, as the shallow depths are not consistent with the large storage volume needed for quantity control, and large surges of water can damage the wetland. A constructed wetland should have a permanent pool zone for treatment and a fluctuating storage zone and discharge control sized for peak runoff rate control. Wetlands should be constructed only for treatment in situations where quantity control is not required. Wetlands are normally constructed with a wet pond, and should have a bleed-down time of 5 days.

At least two distinct cells should be created by restricting the flow to a narrow passageway between high marsh features. The minimum littoral zone is 35% of the site. The wetland should be relatively wide at the inlet to distribute flow, and the distance between the inlet and outlet should be maximized. The preferred effective length-to-width ratio is 5:1, a minimum of 3:1 is recommended. At the entrance to the wetland, a forebay should be created as a separate cell, 4-6 feet deep, and placed where influent water discharges to trap coarse sediments, reduce incoming velocity, and distribute runoff evenly. Maintenance access to the forebay must be provided, with the bed hardened to prevent disturbance during clean out. At the outlet, a micropool should be placed, 4-6 feet deep, with a reverse-sloped pipe installed 12 inches below the permanent pool elevation to avoid clogging. A drain should be installed for dewatering within 24 hours to allow maintenance on the wetland. An emergency spillway is required when the wetland is used for runoff quantity control.

Sheet flow should be created to the maximum possible extent, and where flow must be channeled, multiple meandering channels should be used, with flow velocity minimized to prevent erosion. Open water areas should be interspersed with marsh. A buffer should be provided around the wetland, with a minimum width of 20-26 feet, measured from the maximum water surface elevation, plus 16 feet to the nearest structure. This serves to separate the treatment area from the human community, and reduces exposure of any wildlife to external factors. At least 75% of the buffer should be forested to repel geese and provide better protection and habitat. The maximum side slope should be less than 15% unless a fence is built around the perimeter.

Mosquitoes can be prevented by creating habitats that support predatory insects. Aesthetic considerations can be addressed by establishing attractive vegetative communities. Undesirable plant monocultures can be limited through structural diversity and a range of depths, and by planting diverse native selections.

Loams and silt loams work best to establish plants, capture pollutants, retain surface water, and permit groundwater discharge. Muck soils are favorable for plant and microorganism growth and metal and organic pollutant adsorption. Soils should contain seed banks or rhizomes of obligate and facultative wetland plants, so that vegetation is established more quickly and effectively.

References 13, 16, 35

**Related Facilities:**

Wet ponds; Inflow and outflow structures

References 13, 35

## CONSTRUCTED WETLANDS

**Regulatory Considerations:**

All federal, state, and local laws and regulations must be considered. Archaeological and cultural resources must be avoided, as well as critical wildlife habitat areas. This BMP is widely and frequently used, and is generally acceptable given appropriate site characteristics as described below.

Reference 13

**Overall Advantages/Disadvantages:**

Advantages: Constructed wetlands can be diverse in structure, which offers potential for relatively effective control of most pollutants, and contributes to flood attenuation. They possess a wider range of potential side benefits, and require relatively low maintenance costs. They are more widely applicable and provide more reliable service than infiltration. Aesthetic and habitat benefits are associated with constructed wetlands.

Disadvantages: Constructed wetlands require more land for equivalent service than do wet ponds and other systems, especially if intended to serve quantity as well as quality control purposes. Maintenance and construction costs are higher than those associated with dry ponds. Plants must be well-established before pollutant removal efficiencies reach required levels, and uncertainties in design, construction, and operating criteria exist. Public concern about nuisances must be addressed in siting, design, construction, and operation phases.

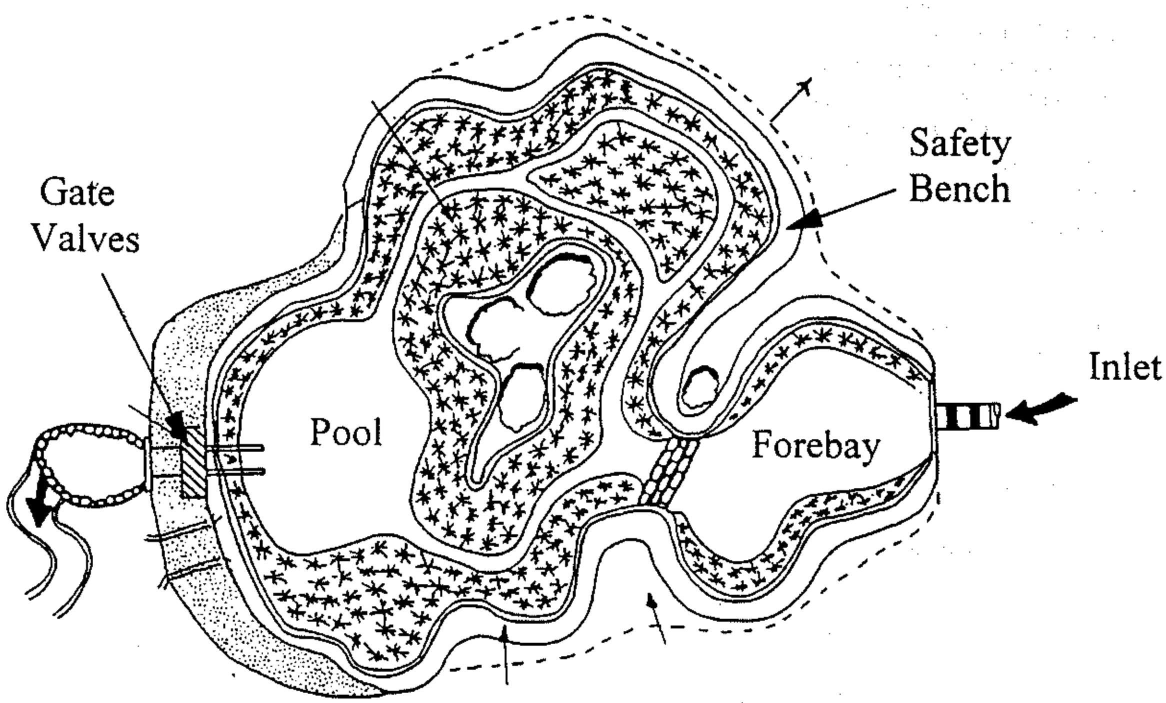
References 13, 16, 19

**Site Constraints:**

| | | |
|---|---|---|
| Treated Area: | 5 - 99 acres | 13, 33 |
| BMP Area: | 1) Range=2% - 5% of total drainage area: typically 0.1-5 acres | 33 |
| | 2) Up to 3,473 acres in North America | 15 |
| Depth to Water Table: | N/A | |
| Site Slope: | 1) Less than 1% along-flow, 0% perpendicular to flow, less than 20% side slope | 13 |
| | 2) Less than 15% side slope without a fence | 35 |
| Soil Permeability: | Less than 0.02 in/hr (clay) to 1.0 in/hr (sandy loam) | 30 |

| CONSTRUCTED WETLANDS | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Mean=25%; Maximum=40%<br>2) Range=-15%-40%; Mean=20%<br>3) Mean=51% | 13<br>21<br>15 |
| TP Removal: | 1) Mean=45%; Maximum=65%<br>2) Range=-120%-100%; Mean=25%<br>3) Mean=31% | 13<br>21<br>15 |
| TSS Removal: | 1) Mean=75%<br>2) Range=-20%-100%; Mean=65%<br>3) Mean=71% | 13<br>21<br>15 |
| Flood Attenuation Capacity: | 1) 2-5 year storm (without auxiliary water body) | 16 |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, vegetation harvesting, sediment removal, structure maintenance, erosion control, debris removal | 19 |
| Relative Level of O&M Required: | Higher than dry ponds | |
| Maintenance Period: | 2-3 times annually | |
| **Costs:** | | |
| Construction: | 1) $2,800/acre treated<br>2) $985 - $134,886 per BMP acre, $23,682 per BMP acre average in North America | 6<br>15 |
| Operations & Maintenance: | 3-5% of construction cost annually: $112 per acre treated | 33 |

# Constructed Wetland Schematic




Adapted from: Schueler (1991)

## VEGETATED SWALE

**Description and Function:**

A vegetated swale is a shallow linear depression, usually grassed, that is used to capture, store, and convey stormwater runoff. Both flood attenuation, through temporary storage and diversion, and water quality treatment, through infiltration, settling of particulate material, and biological uptake of nutrients are provided. Vegetated swales serve as stabilized stormwater conveyance channels and reduce runoff velocities, thus reducing erosion. Swales should be constructed in areas with a low water table and permeable soils so that infiltration can occur, and no standing water will remain except directly following a storm event. Swales may be used in conjunction with other BMPs as part of a treatment train, such as for pre-treatment of runoff prior to discharge to an infiltration basin. Swales may also be used alone with raised outfall structures to promote longer detention times and groundwater recharge.

Vegetated swales are useful as an alternative to ponds in areas where land availability is limited. Many roadway projects, with only a narrow right-of-way to use for stormwater management facilities, often have swales designed for flood attenuation and water quality effects.

The use of vegetated swales is fairly common in Florida. The relatively low cost of construction, ease of maintenance, and convenience in siting (low land requirement) make this an attractive method of stormwater control. Because of their frequency of use, overall effectiveness, and ability to be placed in perimeter zones, medians, or other otherwise unusable portions of sites, vegetated swales are popular with regulators, given appropriate design and site characteristics.

**Design Guidelines:**

Vegetated areas should utilize fine-stemmed plants which exhibit dense, uniform growth and are tolerant of the area's water, climatological, soil, and pest conditions. The best properties are normally found in native plants. A residence time of nine minutes is needed to achieve the highest and most reliable performance, with deteriorated performance when residence time falls below five minutes, recommended as the minimum. Swales should be located away from building and tree shadows to avoid poor plant growth from lack of sunlight. Water-resistant vegetation should be planted if the along-flow slope is less than 2%, or if the water table can reach the root zone. Swale blocks, or check dams, should be constructed every 50 to 100 feet if the along-flow slope is 4% - 6%, to reduce velocity. If the slope on which the swale is installed is greater than 6%, construct the swale so that it traverses the slope, so that along-flow slopes are less than 4%, or less than 6% with check dams. To avoid channelization of flow, make the lateral slope entirely uniform. Inflow velocities to the swale should be reduced quickly, with flow distributed uniformly, to avoid erosion.

The ratio of the top width-to-depth is 6:1 at a minimum, and side slopes of 3:1 are the maximum. Swales should remain wet only during and after a storm event, and SJRWMD require swales to percolate 80% of the 3-year 1-hour storm.

References 4, 13, 16, 36, 43, 45

## VEGETATED SWALE

**Related Facilities:**

Raised outfall structure; Swale blocks; Receiving water ponds

References 16, 19

**Regulatory Considerations:**

Although a relatively common BMP, swales are usually proposed when land availability is an issue, as is the case for narrow sites (roadways). A safety factor of two or more should be applied to the design to account for uncertainty regarding subsurface conditions.

**Overall Advantages/Disadvantages:**

Advantages: Swale systems are a better choice than oil separators to remove low concentrations of oil and grease from urban runoff. Vegetated swales also provide an alternative to ponds where sufficient land is unavailable, and address both water quality and water quantity concerns. Swales are relatively inexpensive to construct and maintain, and can be used as part of a treatment train.

Disadvantages: Vegetated swales are not very effective for phosphorus or nitrogen removal, or for fecal coliform capture. Steep slopes will lead to erosion, and they are ineffective where the water table is high. Standing water in swales promotes mosquito breeding and the growth of undesirable vegetation, and can lead to aesthetic problems.

References 13, 16, 19, 43

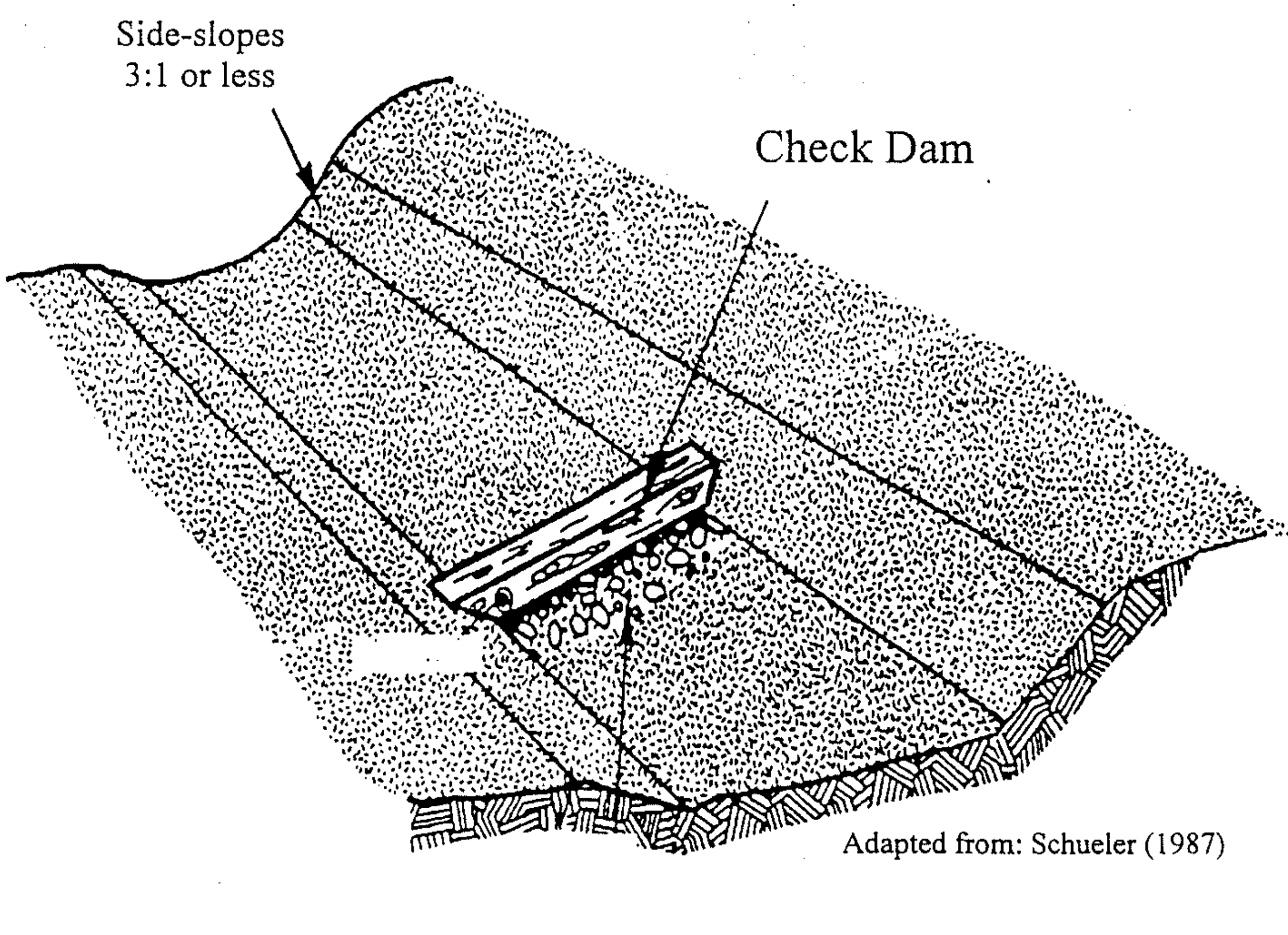
**Site Constraints:**

| | | |
|---|---|---|
| Treated Area: | 1) Maximum=5 acres<br>2) Maximum=150 acres | 14<br>9 |
| BMP Area: | Varies | |
| Depth to Water Table: | Minimum=2 feet | |
| Site Slope: | 1) Less than 20% sideslope<br>2) Less than 11% treated area slope<br>3) Less than 3%<br>4) Less than 5% along-flow slope<br>5) Less than 4% along-flow slope, up to 6% with swale blocks. | 33<br>16<br>14<br>33<br>13 |
| Soil Permeability: | Less than 0.09 in/hr (clay loam) to 8.27 in/hr (sand). | 30 |

| VEGETATED SWALE | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Minimum=10% | 13 |
| | 2) Maximum=25% | 33 |
| | 3) Range=0%-20% for high slope, with no check dams | 30 |
| | 4) Range=20%-40% for low gradient, with check dams | 30 |
| | 5) Range=0%-40%; Mean=10% | 21 |
| TP Removal: | 1) Minimum=10% | 13 |
| | 2) Maximum=30% | 33 |
| | 3) Range=0%-20% for high slope, with no swale blocks | 30 |
| | 4) Range=20%-40% for low gradient, with swale blocks | 30 |
| | 5) Range=0%-100%; Mean=20% | 21 |
| TSS Removal: | 1) Minimum=10% | 13 |
| | 2) Maximum=70% | 33 |
| | 3) 60% | 41 |
| | 4) Range=0%-20% for high slope, with no swale blocks | 30 |
| | 5) Range=20%-40% for low gradient, with swale blocks | 30 |
| | 6) Range=0%-100%; Mean=60% | 21 |
| Flood Attenuation Capacity: | 10-year 24-hour storm | 16 |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, erosion repair, structure maintenance | 19 |
| Relative Level of O&M Required: | Moderate to low, except if designed on inappropriate soils or high water table | 16 |
| Maintenance Period: | 2-3 times annually | 19 |

| VEGETATED SWALE | | | |
|---|---|---|---|
| Costs: | | | |
| | Construction: | 1) $2,300/acre treated | 6 |
| | | 2) $13.25/linear foot | 14 |
| | | 3) $6.83/linear foot for 15 feet wide, 18% sideslope | 30 |
| | | 4) Approximately $1,700/acre for seeding | 30 |
| | | 5) $10,900/acre for sodding | 30 |
| | Operations & Maintenance: | 3-5% of construction cost annually: $92 per treated acre | 13 |

# Grassed Swale Schematic




Adapted from: Schueler (1987)

## VEGETATED FILTER (BUFFER) STRIP

**Description and Function:**

Vegetated buffer strips are best used as borders to areas of impervious surface, and serve to stabilize side slopes, reduce erosion, lower noise levels, slow the velocity of runoff flow, allow some infiltration, capture suspended solids, and remove nutrients through plant uptake. In addition, habitat and aesthetic benefits often result from maintaining vegetated buffer areas, which are also effective when located adjacent to floodplains, wooded areas, and wetlands. Vegetated buffer strips, which are typically 20 to 50 feet wide, may contain either native vegetation that is saved and maintained, or be landscaped. Maintenance of these strips varies depending on the type of vegetation used. Vegetation should completely cover the buffer strip to promote uniform protection. Private land owners can maintain the vegetated buffer adjacent to their property, thus lowering the cost to local governments.

**Design Guidelines:**

Vegetated areas should utilize fine-stemmed plants which exhibit dense, uniform growth and are tolerant of the area's water, climatological, soil, and pest conditions. The best properties are normally found in native plants. A residence time of nine minutes is needed to achieve the highest and most reliable performance, with deteriorated performance when residence time falls below five minutes, recommended as the minimum. Biofilters should be located away from building and tree shadows to avoid poor plant growth from lack of sunlight. Water-resistant vegetation should be planted if the along-flow slope is less than 2%, or if the water table can reach the root zone. Check dams should be constructed every 50 to 100 feet if the along-flow slope is 4% - 6%, to reduce velocity. Inflow velocities should be reduced quickly, with flow distributed uniformly, to avoid erosion. Typical minimum widths of filter strips are in the range of 20-30 feet.

References 13, 16, 19

**Related Facilities:**

Swales and ponds, as part of a treatment train

Reference 19

**Regulatory Considerations:**

Vegetated filter strips are not acceptable for flood attenuation or pollutant removal by themselves, but are usually included as part of local government development standards or comprehensive plans.

**Overall Advantages/Disadvantages:**

Advantages: Vegetated filter strips provide aesthetic and habitat benefits, in addition to erosion control. Construction and maintenance costs are very low, with the maintenance possibly provided by the property owner.

Disadvantages: This BMP does not address regulatory requirements for flood attenuation, and its effectiveness is reduced if the vegetative cover is sparse.

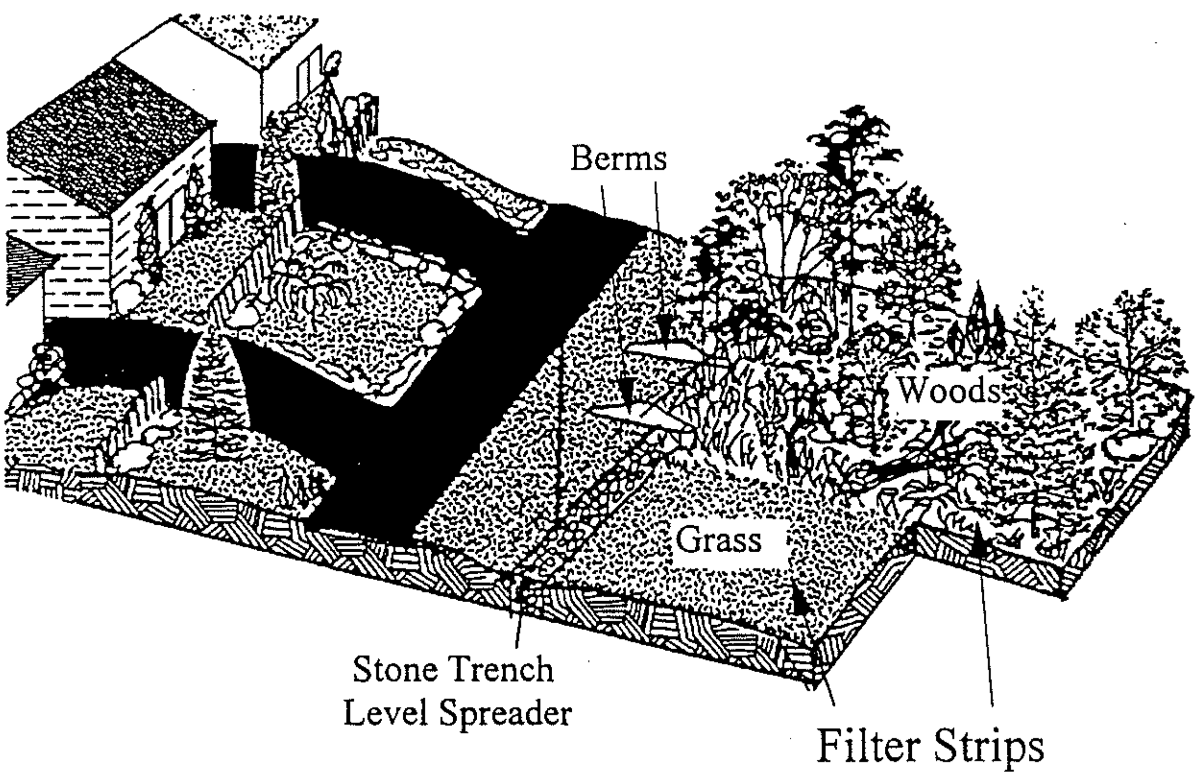
Reference 19

## VEGETATED FILTER (BUFFER) STRIP

| | | |
|---|---|---|
| **Site Constraints:** | | |
| Treated Area: | Less than 5 acres | 14, 37 |
| BMP Area: | 1) 100-300 feet long and 20 feet wide, or 0.05-0.14 acres | 30 |
| | 2) 50-75 feet long and _ feet wide, plus four feet for any one percent increase in slope | 33 |
| | 3) Minimum=20 feet wide | 19 |
| Depth to Water Table: | Maximum=3 feet | 33 |
| Site Slope: | 1) Maximum=5% | 33 |
| | 2) Less than 15% | 30 |
| | 3) Less than 3% | 14 |
| Soil Permeability: | 0.09 in/hr (clay loam) to 8.27 in/hr (sand). | 30 |
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=0%-70% | 41 |
| | 2) Range=0%-20% for 20 foot wide turf strip | 30 |
| | 3) Range=40%-60% for 100 foot wide forested strip, with level spreader | 30 |
| | 4) Range=0%-70%; Mean=40% | 21 |
| TP Removal: | 1) Range=0%-90% | 41 |
| | 2) Range=0%-20% for 20 foot wide turf strip | 30 |
| | 3) Range=40%-60% for 100 foot wide forested strip, with level spreader | 30 |
| | 4) Range=0%-95%; Mean=40% | 21 |
| TSS Removal: | 1) Range=20%-80% | 41 |
| | 2) Range=20%-40% for 20 foot wide turf strip | 30 |
| | 3) Range=80%-100% for 100 foot wide forested strip, with level spreader | 30 |
| | 4) Range=20%-80%; Mean=65% | 21 |
| Flood Attenuation Capacity: | N/A | |

| VEGETATED FILTER (BUFFER) STRIP | | | |
|---|---|---|---|
| **Operations & Maintenance Requirements:** | | | |
| | Required Activities: | Landscaping, erosion control | 19 |
| | Relative Level of O&M Required: | Low, may be performed by property owner | |
| | Maintenance Period: | Varies with type of vegetation | |
| **Costs:** | Construction: | Approximately $1,700/acre with seeding | 33 |
| | Operations & Maintenance: | 2-4% of construction cost annually: $50 per treated acre | 33 |

# Filter Strip Schematic




Adapted from: NJDEP (1994)

## INFILTRATION (DRY RETENTION) BASIN

**Description and Function:**

Infiltration basins are impoundments in which incoming urban runoff is temporarily stored until it gradually leaves the basin by infiltrating into the soil at the bottom and edges of the basin. Stormwater should leave the dry retention basin as surface flow over the spillway only during extreme high flow periods. Filtration (via adsorption and straining) and microbial processes act on the pollutants that enter the soil, with the net result of lower pollutant concentrations in water leaving the soil. The major benefit afforded by infiltration basins is groundwater recharge. Infiltration basins generally have only a slight habitat value. Some concerns have been voiced about potential local groundwater contamination but few data support this concern. The most effective applications of infiltration basins have included a forebay, sediment trap, or vegetated filter strip, where the runoff entering the basin is pretreated to remove coarse sediment that may clog the surface soil pores on the basin floor. Underdrains located at the downstream end of the basin enhance infiltration and direct water to the basin outlet. Other factors that contribute to the success of infiltration basins are non-concentrated flows, dense vegetative cover, short dewatering times, and small contributing basins. Those factors that limit the effectiveness of infiltration basins include high sediment loads, large contributing basins, long dewatering times, high water tables, and clay soils. Infiltration basins should drain within 72 hours to maintain aerobic conditions, which favor bacteria that aid in pollutant removal, and to ensure that the basin is ready to receive the next storm. The life span of infiltration basins is generally short, with most failures due to clogging, often shortly after construction. The standing water that often results from the clogging encourages colonization by wetland vegetation which may provide some water quality benefit not unlike a retention pond.

**Design Guidelines:**

For best operating success, infiltration basins should be built on deep to excessively drained soil, and not near seasonal high water tables or low spots in drainage catchments. Soil is the most critical consideration, and where native soils are inappropriate, a soil system can be constructed with sand and/or peat. Clay soils provide limited percolation, and gravel and coarse sands lead to the risk of groundwater contamination. To prevent clogging, infiltration facilities should require a pretreatment device to settle larger solids and reject runoff from eroding construction sites. Pretreatment should remove 80% of total suspended solids, and the basin should capture the first inch of runoff, with a drawdown time of 72 hours. Banks and other areas must be stabilized to prevent erosion. The facility should be at least 50 feet from any slope greater than 15%, and at least 100 feet upslope or 20 feet downslope of any building. After final grading, so that the bottom is flat, the bed should be deeply tilled, and the basin and sides should be planted with appropriate vegetation, with maintenance for performance and appearance.

References 13, 16

**Related Facilities:**

Overflow spillway and inlet, with erosion control
Reference 19

**Regulatory Considerations:**

Although infiltration basins are not uncommon, their inconsistency and tendency to clog reduce their popularity with regulators.

## INFILTRATION (DRY RETENTION) BASIN

**Overall Advantages/Disadvantages:**

Advantages: Only soil infiltration systems have been reliable in removing soluble phosphorus, and removal efficiencies for total nitrogen and suspended solids are high as well. Infiltration basins provide groundwater recharge, and address both water quantity and water quality concerns.

Disadvantages: Infiltration practices have the highest failure rates among all alternatives, requiring great care in site selection, design, operation, and maintenance. The potential exists for groundwater contamination, especially in karst zones. Infiltration basins are not feasible in areas where the water table is high or soils have low permeability. There are no effective means of preventing clogging of an infiltration basin, and there is distrust among regulatory bodies of this BMP. The land requirement may also be too much for treatment areas of limited size.

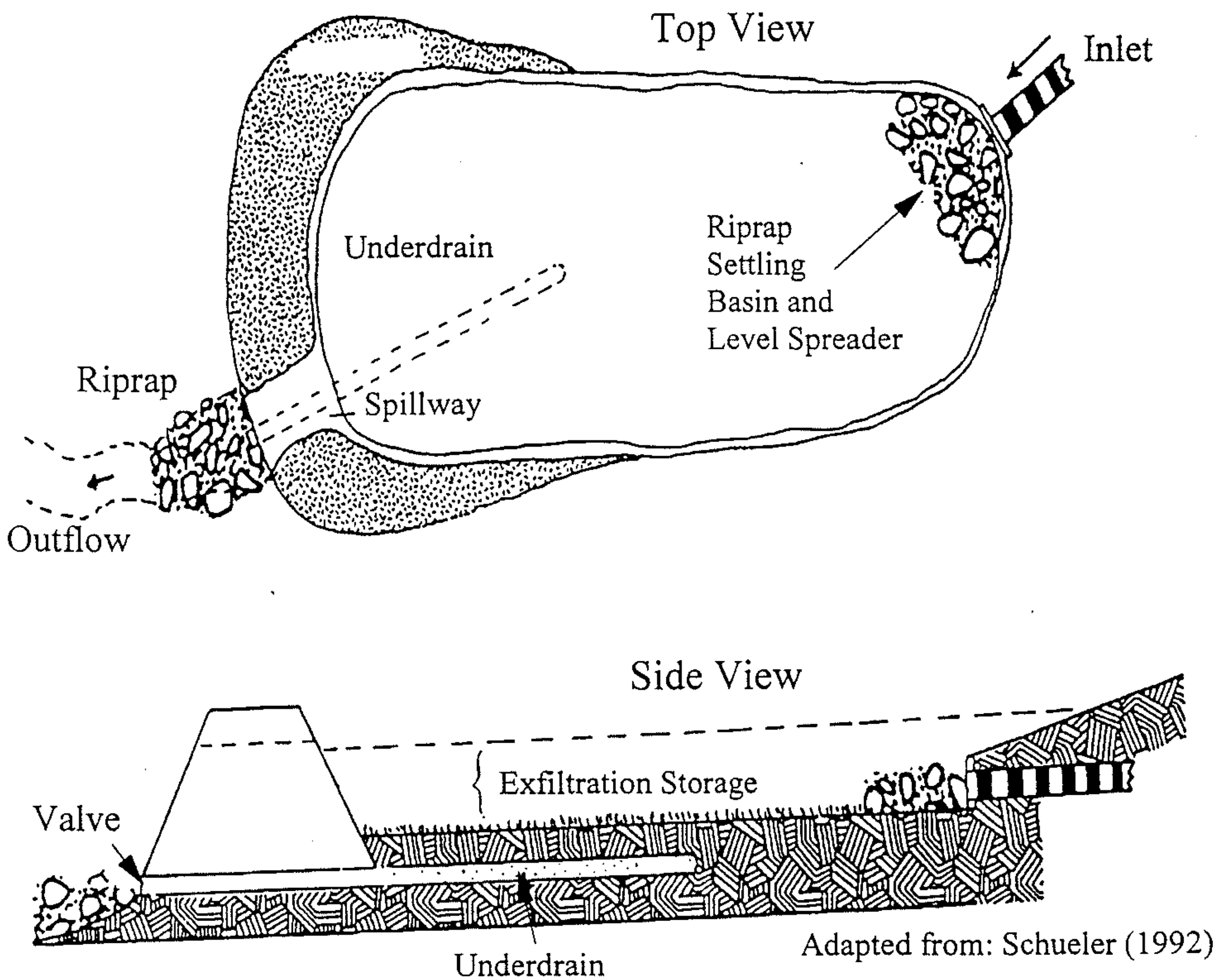
References 13, 16, 19

**Site Constraints:**

| | | |
|---|---|---|
| Treated Area: | 1) Minimum=50 acres | 13, 30 |
| | 2) Range=5-20 acres | 37 |
| | 3) Range=1-50 acres | 30 |
| | 4) Range=2-15 acres | 33 |
| | 5) No minimum | 13 |
| BMP Area: | Range=5-10% of total drainage area: less than 5 acres | 13 |
| Depth to Water Table: | | 33 |
| | 1) 3 feet minimum | 37 |
| | 2) 4 feet maximum | 13 |
| | 3) Bed should be 3-5 feet above water table | |
| Site Slope: | | 30 |
| | 1) Less than 20% treated area slope | 14 |
| | 2) Less than 3% | 13 |
| | 3) Less than 15% slope of BMP site | |
| Soil Permeability: | | 13 |
| | 1) From 0.3-0.5 in/hr | 30 |
| | 2) Maximum percolation rate of 2.4 in/hr when facility provides all runoff treatment and when it drains to groundwater. | 30 |
| | 3) 0.52 in/hr (loam) to 8.27 in/hr (sand) | |

| INFILTRATION (DRY RETENTION) BASIN | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=45%-70% | 13, 30 |
| | 2) Range=40%-60% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre; and exfiltrates 1 inch runoff per impervious acre | 30 |
| | 3) Range=60%-80% exfiltrates all runoff, for 2 year storm | 30 |
| | 4) Range=45%-100%; Mean=60% | 21 |
| TP Removal: | 1) Range=50%-75% | 13, 30 |
| | 2) Range=40%-60% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre; and exfiltrates 1 inch runoff per impervious acre | 30 |
| | 3) Range=60%-80% when facility exfiltrates all runoff, up to 2 year design storm | 30 |
| | 4) Range=45%-100%; Mean=65% | 21 |
| TSS Removal: | 1) Range=75%-99% | 13, 30 |
| | 2) Range=60%-80% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre | 30 |
| | 3) Range=80%-100% when facility exfiltrates 1 inch runoff per impervious acre; and exfiltrates all runoff, up to 2 year design storm | 30 |
| | 4) Range=45%-100%; Mean=75% | 21 |
| Flood Attenuation Capacity: | 25-year 24-hour flood | 35 |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, cutting grass, removal of sediments and debris, scoring of basin bottom to penetrate the surface | 19 |
| Relative Level of O&M Required: | Moderate to low | |
| Maintenance Period: | 2-3 times annually | |
| **Costs:** | | |
| Construction: | Approximately $2,890/acre treated | 33 |
| Operations & Maintenance: | 3-5% of construction cost annually: $115/ treated acre | 30, 33 |

# Infiltration Basin Schematic




Adapted from: Schueler (1992)

## EXFILTRATION TRENCH

**Description and Function:**

An exfiltration trench is a linear excavation that is backfilled with coarse stone aggregate and/or a perforated pipe. Stormwater that enters the trench is detained until it infiltrates into the groundwater through the bottom and sides of the trench, or until it evaporates. Among the benefits of this BMP are flood attenuation, water quality treatment, groundwater recharge and maintenance of base flows. The potential for groundwater contamination does exist with this alternative, but is not well documented. For this reason, and to reduce the potential for clogging the filtration system, exfiltration trenches are often used in conjunction with other stormwater BMPs, such as vegetated swales for pre-treatment and diversion inlets to capture the first flush of runoff, or are used to provide water quantity and quality benefits to small, isolated parts of a site.

Common designs include a relatively narrow (three to five feet wide), shallow (two to eight feet deep) excavated trench with filter fabric covering stone fill, and/or a large diameter perforated pipe, also fabric covered. Because the primary method of treatment and attenuation is through infiltration, exfiltration is only useful in areas where the depth to the seasonal high water table is sufficient (Florida Administrative Code Ch. 40D-4 states one foot minimum). In addition, soils must be permeable enough to allow an acceptable percolation rate (generally over 0.5 to 1.0 inch/hour). Because sediment from runoff can clog the filter fabric and interstitial voids in the stones, periodic maintenance is necessary to sustain exfiltration trenches' efficiency. Filter fabric must be replaced as it clogs, and even the stones should be replaced on a less frequent basis.

The use of exfiltration trenches is limited in central Florida. Their use is more common in the southern part of the state, because there is no design requirement for having the water table below the trench bottom. The relatively high cost of construction, high level of maintenance, requirement for a low water table or high infiltration rates, and frequency of failure from clogging make this BMP most useful only in specific situations, such as those areas where land availability is limited. Infiltration trenches are most appropriate when their ability to be placed in perimeter zones, medians, or other otherwise unusable portions of sites can be exploited.

**Design Guidelines:**

Soil is the most critical consideration, and where native soils are inappropriate, a soil system can be constructed with sand and/or peat. Clay soils provide limited percolation, and gravel and coarse sands lead to the risk of groundwater contamination. To prevent clogging, infiltration facilities should require a pretreatment device to settle larger solids and reject runoff from eroding construction sites. Pretreatment should remove a portion of the total suspended solids to reduce the potential for clogging. Banks and other areas must be well-constructed and stabilized to prevent erosion and subsequent clogging of the exfiltration system. The facility should be at least 50 feet from any slope greater than 15%, and at least 100 feet upslope or 20 feet downslope of any building. Trenches should be at least 3 feet wide, and 2-8 feet deep, with the stone aggregate fill enclosed in a filter fabric, with a maintenance sump at inlets.

References 13, 19, 29, 35, 44

## EXFILTRATION TRENCH

**Related Facilities:**

Other parts of the treatment train, i.e. receiving water pond or swale; Diversion inlets

Reference 19, 29, 44

**Regulatory Considerations:**

Exfiltration trenches are not uncommon for water quality treatment, but are not common for flood attenuation.

**Overall Advantages/Disadvantages:**

Advantages: Only soil infiltration systems have been reliable in removing soluble phosphorus. Trenches provide reduction in stormwater volume and enhance groundwater recharge and baseflow. Trenches can serve small drainage areas, and can be constructed in narrow medians and perimeters to capture the "first flush" of runoff.

Disadvantages: Exfiltration practices have a high failure rates relative to all BMP alternatives, requiring great care in site selection, design, construction, operation, and maintenance. Pollutant removal efficiencies and infiltration capacity may decrease with time, with high maintenance required to keep efficiencies high. The potential for groundwater contamination exists, and trenches are not suitable in areas with high water table or low soil infiltration rates.

References 13, 16, 19, 29, 44

## EXFILTRATION TRENCH

| **Site Constraints:** | | |
|---|---|---|
| Treated Area: | 1) Less than 5 acres | 12,30,33,37 |
| | 2) 1-9 acres | 4 |
| BMP Area: | 1) 150 feet long, 6 feet wide (0.02 acre) | 30 |
| | 2) Side area to bottom area ratio less than 4:1 | 16 |
| Depth to Water Table: | 1) Minimum=3 feet | 12, 33 |
| | 2) Bed should be 3-5 feet above water table | 13 |
| | 3) Minimum=1 foot | 35 |
| Site Slope: | 1) Less than 5% | 12, 30, 33 |
| | 2) Less than 3% | 14 |
| | 3) Less than 20% | 12 |
| | 4) Side slopes of 27% - 34% for sand | 16 |
| | 5) Less than 15% slope of BMP site | 13 |
| Soil Permeability: | 1) Minimum percolation rate of 0.3 - 0.5 in/hr | 13 |
| | 2) Max. perc. rate of 2.4 in/hr when facility provides all runoff treatment and when it drains to groundwater. | 30 |
| | 3) From 0.5 in/hr (loam) to 8.27 in/hr (sand) | 47 |

| EXFILTRATION TRENCH | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=40%-80%; Mean=57% | 14 |
| | 2) Maximum=60% | 33 |
| | 3) Range=-10%-100% | 41 |
| | 4) Range=45%-70% | 30 |
| | 5) Range=40%-60% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre; and exfiltrates 1 inch runoff per impervious acre | 30 |
| | 6) Range=60%-80% when facility infiltrates all runoff, up to 2 year design storm | 30 |
| | 7) Range=-10%-100%; Mean=55% | 21 |
| TP Removal: | 1) Range=40%-80%; Mean=57% | 14 |
| | 2) Maximum=60% | 12, 33 |
| | 3) Range=50%-70% | 30 |
| | 4) Range=40%-60% when facility infiltrates first-flush, 0.5 inch runoff per impervious acre; and exfiltrates 1 inch runoff per impervious acre | 30 |
| | 5) Range=60%-80% when facility exfiltrates all runoff, up to 2 year design storm | 30 |
| | 6) Range=40%-100%; Mean=60% | 21 |
| TSS Removal: | 1) Range=60%-100%; Mean=83% | 14 |
| | 2) Maximum=90% | 12, 33 |
| | 3) Range=45%-100% | 41 |
| | 4) Range=75%-90% | 30 |
| | 5) Range=60%-80% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre | 30 |
| | 6) Range=80%-100% when facility exfiltrates 1 inch runoff per impervious acre; and exfiltrates all runoff, up to 2 year design storm | 30 |
| | 7) Range=45%-100%; Mean=75% | 21 |
| Flood Attenuation Capacity: | Low | |

| EXFILTRATION TRENCH | | | |
|---|---|---|---|
| **Operations & Maintenance Requirements:** | | | |
| | Required Activities: | Inspection and replacement of stones and filter fabric if clogging occurs, maintenance of inlet structures | 16, 19 |
| | Relative Level of O&M Required: | Moderate | |
| | Maintenance Period: | Annual inspection, with stone replacement when reduced functioning is observed | |
| **Costs:** | | | |
| | Construction: | 1) $4/cubic foot, so that 0.5" on 1 acre: $7,300<br>2) Cost=$26.6V_s^{0.63}$<br>3) French drain system, 24-inch pipe costs $28/linear foot (1979 dollars) | 14<br>30<br>30<br>16 |
| | Operations & Maintenance: | 1) 5% - 10% of construction cost annually for surface trench: $550, includes rehabilitation every 5 years | 16, 30 |
| | | 2) 10% - 15% of construction cost annually for underground trench: $910, includes rehabilitation every 15 years | 16, 30 |

## POROUS PAVEMENT

**Description and Function:**

Porous pavement is a high-void aggregate-based paving material (concrete or asphalt) that allows water to flow through it. When used and maintained correctly, flood flows are attenuated and pollutant loading to surface waters are reduced by the seepage of stormwater through the pavement and underlying soils into the groundwater. As stormwaters pass through the pavement and soils, they are stripped of suspended particles, oil and grease, and other pollutants. Another benefit of using porous pavement includes the reduction in stormwater ponding that would occur on impervious pavement. However, because the accumulated particulates and vehicle-based oils and grease tend to quickly clog the pavement pores, frequent cleaning (vacuuming followed by pressure washing or the use of an environmentally-safe solvent) is necessary to maintain effectiveness. In addition, as the subbase soils become more compacted from pavement loads over time, infiltration rates may decrease and the soil may remain saturated for extended periods, thus reducing the structural stability of the paved area. Porous pavement is most appropriate for parking lots or low traffic areas. It should only be used where natural or enhanced subsurface drainage will allow the soils under the pavement to remain unsaturated for most of the time. Because of the limited capacity to reduce runoff volume and the reduced pollutant removal benefits over time, porous pavement is good as a temporary management method, or when used in conjunction with other BMPs. Although porous pavement has been permitted for stormwater management in some specific cases, it is generally not recognized by regulators as a valid permanent solution to runoff management problems.

**Design Guidelines:**

The modular block type of porous pavement system, or a continuous pored layer, can be used. The BMP design consists of perforated concrete slabs underlain with gravel, and is specified for use in low traffic areas like airports, parking lanes, driveways, and paved paths without traffic. Soil is the most critical design consideration, and where native soils are inappropriate, a soil system can be constructed with sand. Clayey soils provide limited percolation, and gravel and coarse sands lead to the risk of groundwater contamination. To prevent clogging, facilities should require a pretreatment device to settle larger solids from off-site flows and reject runoff from eroding construction sites. Removal of suspended solids from stormwater prior to infiltration through porous pavement will reduce the potential for clogging. Banks and other areas must be stabilized to prevent erosion. The facility should be at least 50 feet from any slope greater than 15%. A typical porous pavement system includes a porous concrete surface course (layer) 2.5 to 4 inches thick, underlain by a two-inch thick filter course of ½ inch aggregate. A reservoir base course lies beneath, composed of one-two inch aggregate. The reservoir course thickness is based on site conditions and storage needs, and should be lined with filter fabric. A bottom filter layer may also be installed directly above the filter fabric. The paved area should be flat to allow uniform infiltration, and minimum compaction of the subbase is desirable. The system may require underdrains. The "Pervious Pavement Manual", published by the Florida Concrete and Products Association (1988) provides a thorough description of design criteria for pervious paving.

References 13, 16

**Related Facilities:**

Water quality inlets; Overflow BMPs; Underdrains

Reference 19

## POROUS PAVEMENT

**Regulatory Considerations:**

Porous pavement's low infiltration, high maintenance, and frequent failure make it unpopular in most cases.

**Overall Advantages/Disadvantages:**

Advantages: Porous pavement provides relatively high removal efficiencies via infiltration for total phosphorous, nitrogen, and suspended solids. Porous pavement is used where land availability is a constraint, and reduces ponding.

Disadvantages: Porous pavement is subject to clogging, and is not suitable in areas of high water table or where soils have low infiltration rates. The potential for groundwater contamination exists, but has no been demonstrated. There is a low rate of reduction in runoff volume, required maintenance is high, and failure or greatly reduced effectiveness is likely even with maintenance. A saturated subbase may become structurally unsound.

References 13, 16, 19, 35

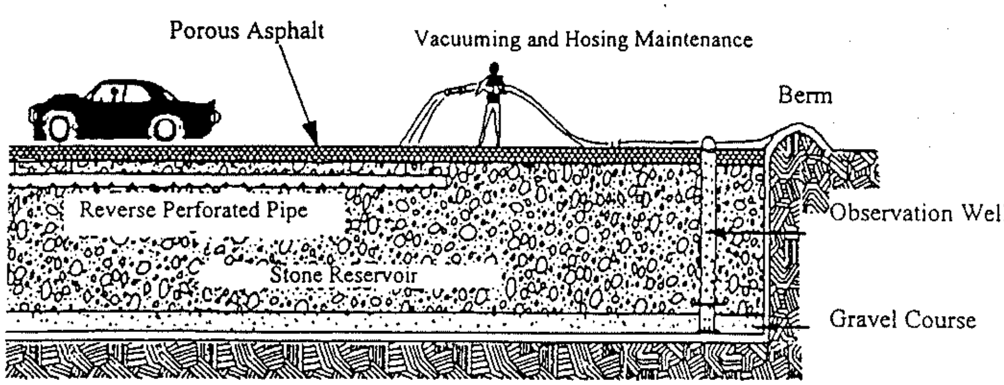
**Site Constraints:**

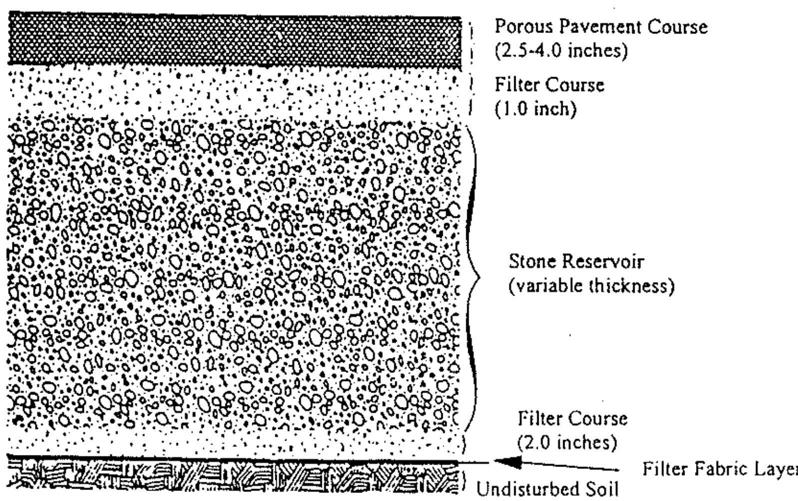
| | | |
|---|---|---|
| Treated Area: | 1) Range=0.25-10 acres | 30 |
| | 2) Less than 10 acres | 33 |
| | 3) Less than 17 acres | 13 |
| | 4) Range=2.5-5 acres | 37 |
| | 5) 10 acres | 12, 33 |
| BMP Area: | Usually used when there is little unused space available: 1 acre | 16, 30 |
| Depth to Water Table: | 1) Minimum=3 feet | 12, 33 |
| | 2) Bed should be 3-5 feet above water table | 13 |
| | 3) Range=2-4 feet | 19 |
| Site Slope: | 1) Less than 5% | 30, 33, 37 |
| | 2) Less than 3% | 14 |
| | 3) Less than 15% slope of BMP site | 13 |
| Soil Permeability: | 1) Minimum percolation rate of 0.3 - 0.5 in/hr | 13 |
| | 2) Maximum percolation rate of 2.4 in/hr when facility provides all treatment and drains to groundwater. | 30 |
| | 3) From 0.5 in/hr (loam) to 8.27 in/hr (sand) | 30 |

| POROUS PAVEMENT | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=40%-80%; Mean=57% | 14 |
| | 2) Range=75%-85% | 30 |
| | 3) Maximum=80% | 12, 33 |
| | 4) Range=80%-85% | 41 |
| | 5) Range=80%-99% | 13 |
| | 6) Range=40%-60% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre | 30 |
| | 7) Range=60%-80% exfiltrates 1 inch runoff per impervious acre; or all runoff, for 2 year design storm | 30 |
| | 8) Range=80%-85%; Mean=85% | 21 |
| TP Removal: | 1) Range=40%-80%; Mean=57% | 14 |
| | 2) 65% | 30 |
| | 3) Maximum=60% | 12, 33 |
| | 4) Range=60%-80% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre; exfiltrates 1 inch runoff per impervious acre; and exfiltrates all runoff, up to 2 year design storm | 30 |
| | 5) Range=60%-90%; Mean=65% | 21 |
| TSS Removal: | 1) Range=60%-100%; Mean=83% | 14 |
| | 2) Range=85%-95% | 30 |
| | 3) Maximum=80% | 1, 33 |
| | 4) Range=80%-95% | 41 |
| | 5) Range=80%-99% | 13 |
| | 6) Range=40%-60% when facility exfiltrates first-flush, 0.5 inch runoff per impervious acre | 30 |
| | 7) Range=8C%-100% when facility exfiltrates 1 inch runoff per impervious acre; and exfiltrates all runoff, up to 2 year design storm | 30 |
| | 8) Range=80%-95%; Mean=90% | 21 |
| Flood Attenuation Capacity: | Low | |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Vacuum or high pressure wash, repair structural faults | 19 |
| Relative Level of O&M Required: | High | |
| Maintenance Period: | 4 times annually | |

| POROUS PAVEMENT | | | |
|---|---|---|---|
| Costs: | | | |
| | Construction: | 1) \$1.5/ft$^2$, or \$65,340/acre of pavement | 14 |
| | | 2) \$1.30 - \$2.00/ft$^2$, or \$56,628 - \$87,120/acre of pavement | 30 |
| | Operations & Maintenance: | \$0.01/ft$^2$ annually, or \$653/acre of pavement | 14 |

Schematic of Porous Pavement System




Adapted from: Schueler et al. (1992)

## MODULAR GRID PAVEMENT

**Description and Function:**

Modular grid pavers consist of strong structural materials having regularly spaced void areas filled with permeable material, such as sod, gravel, or sand, that allows water to flow through it. When used and maintained correctly, flood flows are attenuated and pollutant loading to surface waters are reduced by the seepage of stormwater through holes in the pavers and underlying soils into the groundwater. As stormwaters pass through the pavers and soils, they are stripped of suspended particles, oil and grease, and other pollutants. Another benefit of using modular grid pavers includes the reduction in stormwater ponding that would occur on impervious pavement.

However, because the accumulated particulates and vehicle-based oils and grease may clog the surface pores, cleaning is often necessary to maintain effectiveness. If sod fills the paver voids, typical landscape maintenance is required. In addition, as the subbase soils become more compacted from pavement loads over time, infiltration rates may lower and the soil may remain saturated for extended periods, thus reducing the structural stability of the pavement. Also, if grid pavers leave significant areas of bare soil exposed, erosion may occur, especially on sloped areas.

Pavers are most appropriate for parking lots or low traffic areas. This BMP should only be used where natural or enhanced subsurface drainage will allow the soils under the pavers to remain unsaturated for most of the time. Because of the limited capacity to reduce runoff volume and the reduced pollutant removal benefits over time, pavers are a good temporary management method, and work well when used in conjunction with other BMPs. Although pavers have been permitted for stormwater management in some specific cases, they are generally not recognized by regulators as a valid permanent solution to runoff management problems in some situations. One of their main applications is for new development in urban areas where the drainage system is already at or over capacity.

**Design Guidelines:**

The area in which this BMP is to be used should be flat, and have low vehicular and pedestrian traffic. This system must percolate 80% of the 3-year 1-hour storm in 1 hour.

References 4, 16

**Related Facilities:**

Overflow inlets; Underdrains

**Regulatory Considerations:**

Modular pavers are feasible and acceptable as a substitute for traditional BMPs in certain circumstances.

## MODULAR GRID PAVEMENT

**Overall Advantages/Disadvantages:**

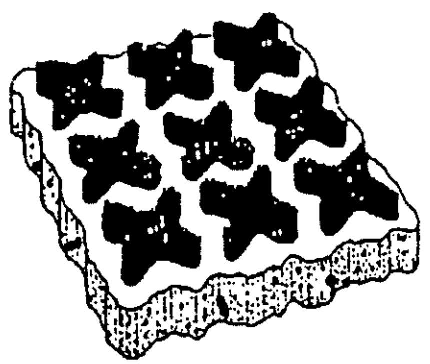
Advantages: Modular pavers can be used in areas of no land availability, promote groundwater recharge, reduce surface water pollutant loads, and reduce surface water flows to some degree.

Disadvantages: Paved areas must have very light or only pedestrian traffic. Modular paving is subject to erosion, and has relatively high maintenance requirements. The potential exists for groundwater contamination as well.

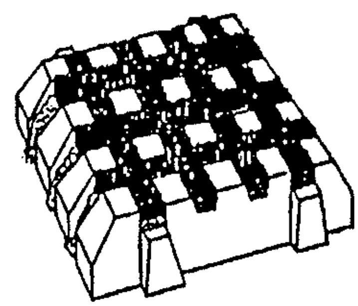
References 13, 16, 31

| | | |
|---|---|---|
| **Site Constraints:** | | |
| Treated Area: | 1 - 10 acres | 14 |
| BMP Area: | Usually used when there is little unused space: 1 acre | 16, 33 |
| Depth to Water Table: | Minimum=3 feet | 33 |
| Site Slope: | Less than 5% | 30 |
| | Less than 3% | 14 |
| Soil Permeability: | From 0.5 in/hr (loam) to 8.27 in/hr (sand) | 30 |
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=60%-90%; Mean=75% | 14 |
| | 2) Range=65%-100%; Mean=90% | 21 |
| TP Removal: | 1) Range=60%-90%; Mean=75% | 14 |
| | 2) Range=65%-100%; Mean=90% | 21 |
| TSS Removal: | 1) Range=60%-90%; Mean=75% | 14 |
| | 2) Range=65%-100%; Mean=90% | 21 |
| Flood Attenuation Capacity: | Low | |

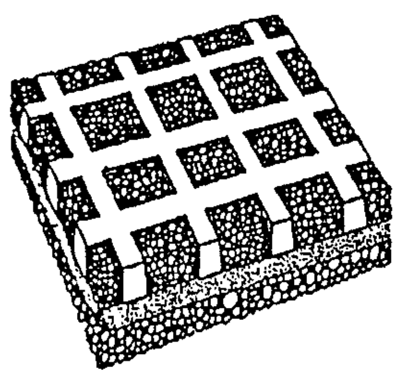
| MODULAR GRID PAVEMENT | | |
|---|---|---|
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Landscaping, repair of erosion impacts | 16 |
| Relative Level of O&M Required: | Moderate | |
| Maintenance Period: | 2 times annually | |
| **Costs:** | | |
| Construction: | $1.0/ft², or $43,560/acre of pavement | 14 |
| Operations & Maintenance: | $0.04/ft² annually, or $1,742/acre of pavement | 14 |



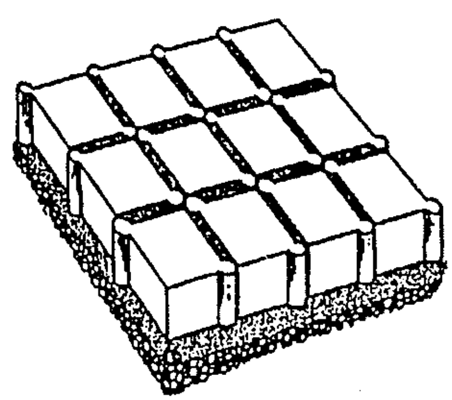
Poured-in-Place Slab



Castellated Unit



Lattice Unit



Modular Unit

From: Livingston et al. (1993)

## WATER QUALITY INLET

**Description and Function:**

Water quality inlets, as their name implies, provide or facilitate water quality treatment, but do not alleviate flooding. They can either be incorporated into newly-designed urban drainage systems, or can be placed in existing systems for retrofits. The specific benefits derived from water quality inlets vary with their design.

The term "water quality inlet" is used here in a general sense and may include one of several principals and designs. One general inlet type is a "smart" inlet that diverts the initial flush of stormwater to another treatment or storage facility and allows subsequent runoff flows to pass by the treatment facility. This type of inlet is most commonly used in association with BMPs of limited capacity, such as exfiltration trenches, underground storage vaults, or parallel pipe storage. The smart inlet has no treatment capacity in itself, but only conveys water to another BMP.

Another general type of water quality inlet is a filter inlet (also discussed in the "Underdrain and Filtration System" section below), which consists of a chamber filled with filter fabric covered with sand, gravel, or other filter material. A sedimentation chamber is also often included to allow larger particles to settle out of the stormwater prior to the stormwater entering the filter chamber. Water that enters the filter chamber must pass through the sand prior to discharging. Pollutants that may be removed from the runoff using sand filters include oil and grease, suspended particles with adsorbed metals and organic compounds, and some nutrients through bacterial action or adsorption of phosphorus. Because the flow rate through a sand filter is very slow in relation to runoff inflows to the inlet, a filter inlet is best designed as an "off-line" chamber. In addition, the accumulation of pollutants and fine particulates in the sand necessitates labor intensive maintenance, which includes cleaning or replacing the filter material.

A variation on these designs is an inlet with built-in skimmers that divert the top layer of runoff with associated oil, grease, and floating debris to an off-line holding chamber for removal by maintenance crews.

Several types of these inlets have been permitted in Florida as alternatives to traditional BMPs in situations where land is not available, where urban growth in already developed areas has overwhelmed the drainage system, or other specialized circumstances. More often, water quality inlets are incorporated into the design of a stormwater management system that includes other BMPs for flood attenuation and more complete treatment.

**Design Guidelines:**

Water quality inlets must be designed to provide adequate treatment yet still convey design storms. They are used for pre-treatment of stormwater prior to the water entering the drainage system.

Reference 19

**Related Facilities:**

Other parts of the treatment train - swales, ponds, underdrains, etc.

**Regulatory Considerations:**

These structures are fairly specialized, and are most feasible for urban retrofits or where land is not available for traditional BMP usage.

## WATER QUALITY INLET

**Overall Advantages/Disadvantages:**

Advantages: This BMP has no land requirement, with filtering inlets most suitable for small areas of mainly impervious land surfaces.

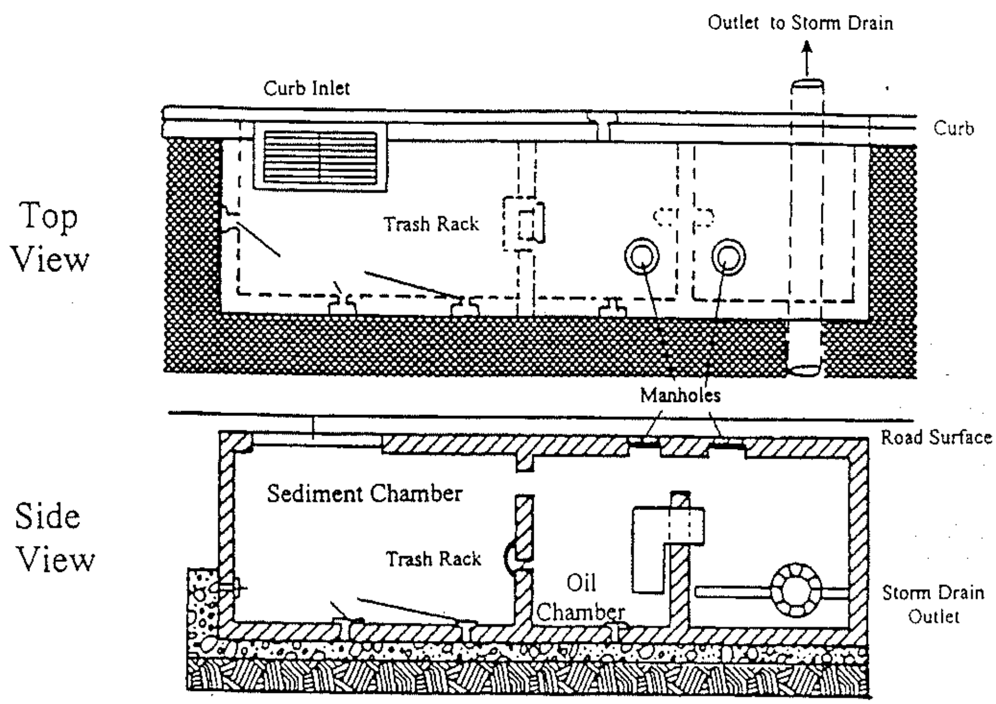
Disadvantages: Some types of inlets are relatively expensive. Sand filter inlets require high maintenance, have limited capacity, and are subject to failure.

Reference 9

| | | |
|---|---|---|
| **Site Constraints:** | | |
| Treated Area: | Less than 2 acres | 33 |
| BMP Area: | 400 $ft^3$/acre, underground | 33 |
| Depth to Water Table: | All | 14 |
| Site Slope: | N/A | |
| Soil Permeability: | N/A | |
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=5%-10%; Mean=8% | 14 |
| | 2) Range=5%-55% | 41 |
| | 3) Range=5%-55%; Mean=20% | 21 |
| TP Removal: | 1) Range=5%-10%; Mean=8% | 14 |
| | 2) Range=5%-10% | 41 |
| | 3) Range=5%-10%; Mean=5% | 21 |
| TSS Removal: | 1) Range=10%-25%; Mean=18% | 14 |
| | 2) Maximum=25% | 41 |
| | 3) Range=0%-20% for 400 $ft^3$ wet storage per impervious acre | 30 |
| | 4) Range=0%-95%; Mean=35% | 21 |
| Flood Attenuation Capacity: | N/A | |

| WATER QUALITY INLET | | | |
|---|---|---|---|
| **Operations & Maintenance Requirements:** | | | |
| | Required Activities: | Clean debris from inlet, change sand from filters | 16, 45 |
| | Relative Level of O&M Required: | Moderate to high | |
| | Maintenance Period: | 1 time annually | |
| **Costs:** | | | |
| | Construction: | 1) \$8,000/unit, \$10 - \$40/ft$^3$ treated<br>2) \$5,000 - \$15,000/unit, \$7,000 - \$8,000 average | 33<br>30 |
| | Operations & Maintenance: | \$600 annually | 20 |

## Water Quality Inlet Schematic




Adapted from: NJDEP (1994)

## UNDERDRAINS AND FILTRATION SYSTEMS

**Description and Function:**

The central principal of underdrain systems is to collect and convey stormwater through a system of pipes or gravel-filled trenches after the stormwater has infiltrated into the soil. This method of stormwater treatment may be incorporated into a detention basin, or it may be constructed as a separate linear or grid system of conveyances. When used in concert with a detention pond, underdrains provide enhanced infiltration so that when stormwater enters the basin it is retained until it infiltrates into the groundwater, evaporates, or transpires. No stormwater should leave the facility as surface water, except under very high flows via an emergency spillway. Flood attenuation (lower peak flow rates and volume reduction), base flow maintenance, and water quality benefits result from the use of this BMP.

Underdrains are typically constructed by burying a perforated pipe wrapped in filter fabric, or by excavating a trench, lining the trench with filter fabric and then partially filling the trench with gravel covered with filter fabric, and filling the top of the trench to grade with dirt. A layer of tile drains may also be used. This serves to intercept infiltrated stormwater and direct it to areas where the water can dissipate into the surficial aquifer. Although a certain amount of natural infiltration is necessary to make this BMP function, areas with low infiltration often most appropriate for using underdrains.

Filtration systems are of similar design but serve a different purpose. Stormwater filters typically are constructed of a series of filter fabric-wrapped perforated pipes or gravel filled trenches surrounded by a sand layer designed to provide water quality treatment through filtration of infiltrated stormwater. Filters are often constructed in the banks or near the outfall structure of detention areas to treat, intercept, and collect infiltrated stormwater prior to discharge from the detention area. Filters may be used for underdrains that discharge stormwater to the surficial aquifer, or may be a last treatment step prior to discharge via the surface water flow.

Because infiltration is the primary treatment means and discharge pathway, it is important to prevent clogging of the underdrain system, and associated detention basin bottom. To this end, a sediment trap should be constructed to allow particulate material to settle out of the stormwater prior to entering the basin. The sediment trap should be cleaned periodically, and the basin bottom should be cleaned and scarified to maximize infiltration rates.

Underdrain and filtration systems used with detention basins are not uncommon, but are not as readily accepted as other (wet detention basins) BMPs, mainly because of the relatively high construction cost (for enhanced systems), requisite high level of maintenance, frequency of failure, and reliance on subsurface conditions to allow continued infiltration. Under desirable site conditions filtration basins work very effectively, but their reliability is much reduced under adverse conditions (clogging, high water table, etc.).

## UNDERDRAINS AND FILTRATION SYSTEMS

**Design Guidelines:**

Small sites are generally most appropriate for this BMP, (less than 5 acres). The planning and design of underdrains and filters entails several steps, including a site reconnaissance (survey, determination of water table depth and infiltration rates, etc.), determination of the length, spacing, and volume of underdrains required to drain and filter the regulatory volume within 72 hours, and integrating the underdrain and filters with a detention pond, if appropriate. Minimum pipe diameter is 12 inches and minimum trench width is 3 feet. Filter fabric must wrap material in trenches and a sediment sump is required at the inlet. Design criteria and methods for design of underdrains and filtration systems are thoroughly discussed by Livingston et al. (1988).

References 13, 16, 35

**Related Facilities:**

Inlets, detention ponds, other parts of treatment train

**Regulatory Considerations:**

Underdrains and filtration systems are perceived as requiring high maintenance and being subject to clogging. They are not popular with regulators, but are permitted as a General Permit.

**Overall Advantages/Disadvantages:**

Advantages: This BMP requires limited land surface, recharges groundwater, and enhances low natural infiltration rates.

Disadvantages: Underdrains and filters are subject to clogging thus often requiring maintenance, and the potential for groundwater contamination exists.

**Site Constraints:**

| | | |
|---|---|---|
| Treated Area: | 1) 0.5 - 50 acres | 14 |
| | 2) Less than 5 acres (sand filter) | 13 |
| BMP Area: | 1) 5-10% of total drainage area: 0.03-5 acres | 30 |
| | 2) 360 $ft^2$/per treated acre, at least 18 inches deep | 13 |
| Depth to Water Table: | 2 - 4 feet minimum | 33 |
| Site Slope: | 1) Less than 5% for basin floor | 30 |
| | 2) Less than 3% | 14 |
| Soil Permeability: | From 0.5 in/hr (loam) to 8.27 in/hr (sand) | 47 |

| UNDERDRAINS AND FILTRATION SYSTEMS | | |
|---|---|---|
| **Operational Efficiencies:** | | |
| TN Removal: | 1) Range=20%-40%<br>2) Range=75%-87%<br>3) Range=20%-40%; Mean=35% | 41<br>13<br>21 |
| TP Removal: | 1) Range=0%-90%<br>2) Range=19%-61%<br>3) Range=0%-90%; Mean=50% | 41<br>13<br>21 |
| TSS Removal: | 1) Range=60%-95%<br>2) Range=75%-87%<br>3) Range=60%-95%; Mean=80% | 41<br>13<br>21 |
| Flood Attenuation Capacity: | 25-year 24-hour flood | 35 |
| **Operations & Maintenance Requirements:** | | |
| Required Activities: | Clear debris from structure, change sand in filter as needed | 16, 19 |
| Relative Level of O&M Required: | Moderate to high | |
| Maintenance Period: | Clean inlet - 2-3 times annually. Replace sand every 1-2 years | |
| **Costs:** | | |
| Construction: | $6,375/acre treated | 33 |
| Operations & Maintenance: | 5% of construction cost annually: $320 per treated acre | 33 |

## 2.4 Other Urban Best Management Practices

The following descriptions are for those BMPs that are in some ways less capital-intensive and less traditional. These BMPs have been grouped as being nonstructural, structural or erosion controls. For each BMP the objective being addressed, the principle underlying the practice, and a description of the BMP are presented.

- **Nonstructural Source Controls**

The traditional approach to utilizing stormwater BMPs involves the placement of structural facilities intended to remove pollutants from the runoff stream. This methodology assumes that runoff has become contaminated, and works to reduce loadings after potentially harmful chemicals have already entered the environment, the remedial approach. An alternate, pro-active, approach for limiting stormwater-borne pollution is to control the amount of chemical compounds that enter the environment and runoff at the chemicals' source.

Limiting the initial distribution of chemicals into the environment is preferred to cleaning up polluted stormwater for several reasons. Traditional stormwater treatment facilities do remove pollutants from the runoff at the time of treatment, but the pollutants in many cases are not "removed" from the environment but are only detained, for example, in pond sediments. Although providing a sink to accumulate harmful substances is beneficial in many ways, a disturbance to the system such as extremely high floods or a physical disruption to the treatment facility such as dredging can re-introduce the pollutants into the surface water system. Reducing the amount of chemicals that enter the environment in the first place removes the risk of pollutants re-entering surface waters in the future. In addition, limiting the release of excess polluting chemicals reduces the amount of fertilizer, pesticides, etc. that must be used to accomplish their purpose, and results in cost savings to the users.

Source control can include a variety of approaches such as user education as to the optimal application rates and methods for a compound, packaging information, promoting good disposal practices of contaminated material such as empty containers, as well as activities such as street sweeping, cleaning construction debris, etc. An important aspect of source control is to change longtime habits of use and disposal of potentially contaminating materials. For example, longtime users of agri-chemicals may be reticent to change practices to more environmentally friendly biological controls. Also, good housekeeping measures such as frequent removal of debris from construction sites can prove very effective in pre-empting pollutant loading to surface waters. The following table summarizes the objectives, principles, and methods of implementing various source controls on stormwater pollutants.

| Fertilizer Application Control | References: 16, 19, 45 |
|---|---|

**Objective:**

The objective of fertilizer application control is to limit the amount of fertilizer that is applied on agricultural, residential, or commercial land to the optimal rate, without overfertilizing.

**Principle:**

Excess fertilizer that is put on the land is not assimilated by the plants and can be washed off to contribute to pollutant loading to surface waters. Excess fertilizer can also seep into groundwater to cause elevated nutrient levels in the surficial aquifer. By limiting fertilizer application, only as much material as the plants can assimilate will be applied to the land, thus reducing the potential for nutrient-rich runoff to damage receiving waters.

**Description:**

This management practice can be implemented through public education, packaging labels stressing the results of over-fertilizing, use of alternative or natural fertilizer products, and optimizing the application times of fertilizer. Also, soil testing may reveal the best mix of fertilizer to obtain good plant growth. Other techniques, such as the application of fertilizer in irrigation water, "fertigation", can be used. The unnecessary loss of fertilizer can also be reduced by controlling erosion, as described below. Knowledgeable groups such as the Cooperative Extension Service or the USDA Natural Resources Conservation Service may be queried for methods to optimize fertilizer application.

| Solid Waste Collection and Disposal | References: 16, 19 |
|---|---|

**Objective:**

The objective of reviewing solid waste practices is to reduce pollutant loadings to urban stormwater resulting from solid waste handling, storage, and disposal methods.

**Principle:**

The generation of and the need to dispose of solid waste is a fact of life. However, if precautions are not taken to limit the exposure of waste materials to the environment, pollutant loadings to surface water and groundwater can increase because of unnecessary contact between solid waste material and the air, rainfall, and stormwater runoff.

**Description:**

Improvements to solid waste management techniques may include public education, revised procedures for the handling and collection of waste vegetative matter (leaves, landscape debris, etc.), disposal and collection of white goods and other potential contaminants, opportunities for recycling, etc.

| Pesticide Use Control | References: 16, 19, 45 |
|---|---|

**Objective:**

The objective of pesticide use control is to limit the amount and extent of pesticides that are released into the environment.

**Principle:**

The excessive use of pesticides can result in unnecessary impacts to living organisms, including humans. By limiting the use of these chemicals to the appropriate application procedures and rates, and by using alternate pest control methods, pesticide loadings to surface waters can be lowered and the potential for environmental degradation can be reduced.

**Description:**

Several mechanisms can be used for this objective, including legal requirements for pesticide application, stringent review of minimum useful application rates, methods of application, equipment cleaning, disposal of unused chemicals and empty containers, chemical storage, alternate pest control methods (such as crop rotation or biological controls), and public education. Both commercial scale and private home owners are subject to these issues. The unnecessary loss of pesticides can also be reduced by controlling erosion, as described below. Knowledgeable groups such as the Cooperative Extension Service or the USDA Natural Resources Conservation Service may be queried for methods to optimize pesticide application. Integrated Pest Management (IPM) combines all approaches in pest reduction using a thorough understanding of pest life cycles and constraints of the site.

The following guidelines may be used for pesticide management:

- it is generally best to use the least toxic material that will accomplish the purpose.
- pesticides that degrade the most rapidly are least likely to become water pollutants.
- pesticides with low solubility in water are less likely to cause water pollution by dissolving in stormwater runoff.
- broad spectrum pesticides should be used instead of a series of chemicals with very specific target applications.
- improve pesticide labeling - use larger print for legibility and make directions more easily understood

All labeling should be read to determine the best methods of application. Application rates may be influenced by the following factors:

- weather, climate, and seasonal characteristics;
- characteristics of soils, terrain, geology, etc.;
- presence of fish, wildlife, humans, livestock, or other non-target organisms; and
- drainage patterns.

| Source Control on Construction Sites | References: 16, 19 |
|---|---|

**Objective:**

The objective of implementing source control on construction sites is to reduce the potential for increasing stormwater pollutant loadings through contact with construction debris, erosion of bare earth construction sites, inappropriate handling of hazardous materials at sites, etc.

**Principle:**

Many activities take place at construction sites that may impact stormwater runoff. Disturbed land is subject to increased erosion, trash and debris from construction sites may end up in runoff stream, and hazardous contaminants such as paint and stains, gasoline and oils, etc. may be spilled or otherwise released into the environment. Several steps can be taken to reduce the risk of such occurrences.

**Description:**

This management practice includes safe materials handling and plain "good housekeeping". Impacts from erosion can be minimized by grading the site to retain all runoff in temporary or permanent detention basins, protecting storm drain inlets, using erosion control barriers such as hay bales or silt screen, and keeping as little of the site unvegetated as possible. Materials handling procedures include keeping chemicals and toxic materials in covered, locked storage areas, cleaning up the site and removing trash and debris at the end of each day, cleaning up spills when they happen, designating protected areas for equipment and machinery cleaning, and using proper sanitary controls.

| Street Cleaning | References: 16, 19, 45 |
|---|---|

**Objective:**

The objective of street sweeping is to remove pollutants, including oil and grease, other organic materials, metals, dust and particulate matter, and deposited atmospheric pollutants from the street surface before it is entrained or dissolved in stormwater runoff.

**Principle:**

Urban roads and streets are virtually impervious, so all rainfall that lands on the road surface becomes runoff. Thus, all pollutants on the road will enter the runoff stream unless removed prior to rain. Street sweeping physically removes the dry weather accumulation of these chemicals for safe disposal.

**Description:**

Street sweeping uses vacuuming, brush sweeping, water sprays, or other physical processes to remove pollutants from street surfaces. This technique is used with varying success on roads, parking lots, driveways, and all hard surfaces subject to vehicular traffic. Studies have shown that the frequency of street sweeping greatly affects the effectiveness of this management practice.

- Structural Runoff Controls

Structural runoff controls are the most commonly used means of managing stormwater quantity and quality. Ponds, swales, diversions, drains, and filters are included in this category of runoff BMPs. Some of the most commonly applied structural BMPs have been discussed in detail in preceding section. The following tables summarize the objectives, principles, and methods of addressing stormwater management issues through the implementation of some of the less-frequently used structural BMPs. There are many factors that affect the likelihood of a particular type of BMP being used in a given situation. Some of the important aspects of BMP selection are cost, site physical characteristics (site size and shape, depth to water table, soil permeability, surface slope, vegetative cover), land availability for BMP use, level of effort required for operating and maintenance, permittability, and design life of the facility. The integration of all these factors results in a determination of the feasibility of using one or more BMPs of a certain type. The BMPs described in the preceding section have repeatedly ranked high in one or more of the limiting BMP selection criteria, resulting in their frequent application in a wide variety of circumstances. Other BMPs, while not as widely usable as those listed above, have their own merits for certain situations. For example, a BMP such as porous pavement may not be practicable for use in most cases because of its cost, maintenance requirements, and low volume capacity. But in some situations, such as an urban retrofit site with no available open land, it may be the most feasible option.

Therefore, the following BMPs should be considered for use where one or more selection factors make the use of a traditional BMP infeasible. It should be noted that, for practical considerations, the selection criterion that most influences BMP selection is cost. If site characteristics make the use of several different types of BMPs equally feasible, the least expensive alternative will usually be selected. The cost of a BMP involves several considerations, including the cost of land necessary to place the BMP, construction cost, operating cost, aesthetics, and maintenance or replacement cost. These costs must be integrated over the design life of a BMP to determine the real or relative cost of feasible alternatives. As site physical characteristics become more restrictive, more expensive BMP alternatives must be considered.

| **Rooftop Runoff Storage** | References: 16, 19, 45 |
|---|---|

**Objective:**

The objective of rooftop runoff storage is to replace direct connections of roof drains to storm sewers with local stormwater dispersal systems that dispose of runoff without burdening the regional drainage system.

**Principle:**

Roof drainage represents virtually 100% of the rainfall that falls on the roof surface, as no infiltration (hopefully) occurs. It is practical in many cases to "disconnect" the link between roof drains and the storm sewer system, and to promote localized stormwater management practices.

**Description:**

Site-specific disposal of roof drainage can be accomplished through a variety of small-scale methods, including french drains or exfiltration trenches, cisterns used to recycle rainfall for landscape irrigation, on-site underdrain systems, etc. These systems can be designed into the building's original stormwater plans, or can be added later. Many of these methods are relatively inexpensive, if sufficient land is available.

| Parking Lot Storage | References: 16, 19, 45 |
|---|---|

**Objective:**

To attenuate flood peak flows through temporary storage of stormwater in parking lots.

**Principle:**

Many parking lots, especially for large commercial sites, are designed to be at capacity for only a few days per year. The resulting excess surface area is therefore generally available to assist in the storage of temporary stormwater prior to entering the drainage system. This technique can be especially useful in urban areas where the existing drainage system has reached its capacity. By holding stormwater directly in the parking lot and gradually releasing it, peak flood flows can be reduced.

**Description:**

Many parking lots, especially large commercial lots, have many empty spaces except for a few days each year. It may be feasible to construct a temporary retention area in the vacant portions of the parking lots to assist in stormwater management. Also, new parking lots may be designed in terraced levels to designate the lowest level as a stormwater storage area. It would be necessary to maintain the safety and convenience of the individuals parking in the lot, but the expanses of asphalt commonly seen around shopping malls could well be used for this purpose. Runoff would be drained from the lot via site grading, porous pavement, modular grid pavers, or inlets and underdrains.

| Physical Treatment | References: 16, 19 |
|---|---|

**Objective:**

The objective of physical treatment alternatives is to provide water quality treatment using processes more commonly employed for potable water treatment.

**Principle:**

In some cases, it is feasible to utilize processes normally used to treat potable water, or domestic or industrial sewage to treat stormwater runoff. This alternative is especially attractive in highly concentrated runoff, or if stormwater has become contaminated on a site (at airplane deicing stations, for example), and must be treated prior to leaving the site.

**Description:**

Processes such as settling, filtration, screening, flocculation, and disinfection may be used. Also, use of a mechanical oil/water separator may be called for in some circumstances, often in conjunction with other, conventional BMPs. These unit processes may be used at a small scale and using simple technology so as to not cost as much as an equivalent process on a treatment plant scale.

| Alum Injection | |
|---|---|

**Objectives:**

The objective of alum injection is to provide a chemical means of flocculating suspended material into particles large enough to settle out of the water column, subsequently removing the pollutants that adhere to the particulate matter.

**Principles:**

Suspended particles in stormwater are solid, but are very small and may remain suspended even with very low flow rates. Many compounds, including metals, organic compounds, and phosphorus, tend to adhere, or adsorb, to these particles. Adding alum to stormwater can promote small particles to bind together (flocculate). The larger pieces of solid material will more readily sink to the bottom of the water column and become bound to sediments, thus stripping the water of pollutants.

**Description:**

Alum addition can be accomplished through several approaches. Open water bodies such as lakes can benefit from "whole lake" treatment, in which alum is added to the lake surface from a boat or airplane. Floc forms as particulate material aggregates and the enlarging solids sink to the bottom, becoming bound to existing sediments. Also, alum can be injected directly into stormwater. The direct injection approach has both positive and negative aspects. Suspended material in stormwater can be inoculated directly, without waiting for it to reach a receiving water body. However, the potential for aluminum toxicity to benthic organisms resulting from settled floc remains an unresolved issue. Application to a lake takes advantage of the buffering activity that will have occurred once the runoff mixes with the lake waters. Also, the equipment required for stormwater injection of alum is relatively expensive, and high levels of operating and maintenance activities are necessary. Whole lake treatment requires much less expensive equipment, and little or no maintenance is required.

- Erosion and Sediment Control Practices

Stormwater runoff can be a powerful physical process, and is capable of removing significant amounts of soil from a site. The subsequent pollutant load of suspended solid (particulate) material can cause environmental degradation by silting over wetland areas or smothering benthic habitats, producing sediment loads that clog streams, ditches and other surface water conveyances, or by transporting other pollutants such as metals and organic compounds. Erosion also results in problems for many types of urban land, and can make roads, foundations, bridges, drainage structures, and other infrastructure physically unstable. However, methods do exist to reduce soil loss and erosion, and subsequently reduce potential harm to the environment. A review of erosion and sediment control practices is also given in Livingston et al. (1998).

Erosion and sediment control practices are often considered as a sub-category of stormwater management BMPs. Although most stormwater BMPs directly or secondarily act to remove suspended particulate material (sediments) from runoff, some types of BMPs are more effective at this than others. In general, ponds, created wetlands, and other BMPs that serve to slow runoff flow velocities or entrap suspended particles are best suited to sediment control.

Other stormwater management practices help to limit the amount of soil lost to runoff and on-site erosion by reducing the potential for erosion to occur at all. These practices are essentially source controls for erosion control, similar in concept to chemical source controls addressed above. Two general types of erosion controls are structural and vegetative practices. Structural erosion control practices use site grading to divert on-site runoff to temporary holding ponds, silt screens, stabilizing exposed soils and drainage ditches, diversion berms, drains, and other constructed measures to control runoff on a site. Vegetative controls include preparing a site for planting, and planting ground cover, establishing vegetated buffer strips adjacent to areas of exposed soils, mulching or grassing exposed soils, etc. Both these measures can be effective erosion control methods, if implemented properly, as described below.

- Structural Practices

Structural erosion control practices include any constructed means of preventing significant loss of soil from a site through the action of stormwater runoff. As stated above, the control of soil loss can occur either as a recovery of particulate material from runoff after erosion has occurred, or as a pro-active means of preventing soils from being entrained in runoff altogether. Many structural methods of accomplishing these objectives are commonly used today. Although land with little topographic relief, such as many of Florida's coastal communities, does not have as great a potential for erosion as more pronounced variation in land surface elevation, providing erosion is still a problem, especially under certain conditions such as on construction sites or along stream channels.

Structural erosion control practices may include activities such as stabilizing areas subject to vehicular traffic, stabilizing areas of exposed soil or around drainage structure inlets and outlets, site grading to retain stormwater on-site, constructing temporary or permanent berms to divert stormwater to sedimentation basins, erecting silt barriers, providing erosion-resistant runoff conveyances such as concrete or rip rap lined channels, constructing subsurface drains to channel runoff down steep slopes without causing erosion, and other methods. The following table summarizes some of these alternatives.

| Road Stabilization | References: 16, 19 |
| --- | --- |

**Objective:**

To minimize sediment loss and erosion from disturbed land during construction activities.

**Principle:**

Allowing exposed soil to erode during site or roadway construction activities increases the pollutant load on surface water bodies through the entrainment of particulate materials in stormwater runoff. Temporary measures can be taken to stabilize construction site access points and roadways to reduce the potential for erosion during construction, before areas are stabilized with vegetation, pavement, or rip rap.

**Description:**

Gravel and small stones used to construct a temporary pad at the ingress/egress point of a construction site. This reduces the amount of dirt carried onto the road from the site, and prevents rutting and damage to the edge of the roadway. Gravel can be used as a temporary road bed material prior to final treatment (paving) to reduce erosion of the roadway. Parking areas, driveways, and access points can also be covered with gravel for the same effect.

| Sediment Barriers | References: 16, 19 |
| --- | --- |

**Objective:**

To construct a physical obstruction to prevent particulate matter from leaving a site entrained in stormwater runoff.

**Principle:**

Allowing exposed soil to erode, especially during construction activities, increases the pollutant load on surface water bodies through the entrainment of particulate materials in stormwater runoff. Measures can be taken to reduce the potential for erosion during construction, or on a permanent basis.

**Description:**

Several types of sediment barriers can be used to reduce the amount of particulate matter entrained in stormwater. Hay bales can be arranged in single or double rows along a toe of a slope, or at the lowest edge of a construction site, and staked for stability. This will retain suspended sediment and slow runoff flow velocity. Using the same principle, a silt fence, or screen, can be constructed using filter fabric supported by stakes. Silt fences are usually temporary erosion control measures. Sediment barriers can also be constructed of brush, limbs, vines, or other material found on-site to obstruct sediment release and slow runoff flows. Sediment barriers are often subject to deterioration after a short time in use and should be regularly inspected and replaced. An alternative to sediment barrier construction is to erect a partial barrier to flows at drop or curb inlets using hay bales. This is most often implemented during construction activities, and should be designed to not impede high flows.

| Dikes and Diversions | References: 16, 19 |
|---|---|

**Objective:**

The objective of using a dike for surface water flow diversion is to direct stormwater runoff to treatment areas, or to keep stormwater on a site, so as to minimize soil loss and pollutant loadings from erosion.

**Principle:**

Stormwater runoff can be managed on a site by constructing temporary or permanent dikes or berms to divert the flow to treatment areas, or to otherwise manage the flows. Diversions are used to retain stormwater on-site, to intercept overland flow on a slope, to slow runoff flow velocity, or to control on-site flow patterns and prevent off-site discharge. This allows particulates to settle out of runoff and not be transported into receiving surface waters.

**Description:**

Diversion berms can be constructed at the toe of a slope to direct runoff to a temporary or permanent storage or treatment facility, thus preventing runoff-borne sediment from leaving the site. On construction sites, temporary berms may be located at the lower edge of areas of disturbed land with exposed soils, directing runoff away from areas with high erosion potential. Small berms may also be constructed parallel to site slopes mid-way down the slope to reduce the flow path length and intercept sheet flow before erosion occurs. Runoff can then be directed to a stabilized area. Such diversion structures are effective on either a temporary or permanent basis, and can be incorporated into site landscaping.

| Sediment Traps and Basins | References: 16, 19 |
|---|---|

**Objective:**

The objective of sediment traps and basins is to provide a receiving area for sediment-laden runoff. This reduces suspended solids loading in surface runoff, and retains stormwater to reduce erosion.

**Principle:**

Sediment traps and basins provide an area to collect runoff and allow sediment to settle out of the water column. Particle settling occurs as the flow velocity of the runoff drops upon entering the basin. Solids and associated pollutants are thus left behind in the trap as the runoff discharges off-site or infiltrates into the groundwater.

**Description:**

Sediment traps and basins can be used as temporary storage and treatment areas during construction, or on a permanent basis. They can be used as isolated settling ponds, or be incorporated into other stormwater treatment and storage facilities. For example, sediment basins, sometimes called "forebays", are used as the initial impoundment that runoff enters, slowing flow velocity and allowing particulate materials to settle out. The clarified stormwater then flows to another storage and treatment area without its initial load of sediment. This serves two purposes: accumulated sediment is easily removed from the smaller forebay trap, and the sediment does not enter the main storage/treatment facility. By removing sediment first, infiltration rates in the main pond are maintained, and potential impacts to emergent vegetation in the main pond resulting from sediment accumulation are minimized.

| Subsurface Drain | References: 19 |
|---|---|

**Objective:**

The objective of using subsurface drains is to move excess water away from surficial soils, to prevent excess moisture from creating unstable soil conditions and allowing subsequent erosion.

**Principle:**

Excess moisture in surficial soils causes soil saturation and a diminishing of the soil stability. Removing excess soil water reduces the tendency for erosion.

**Description:**

A perforated pipe, usually small diameter, can be buried underground in areas subject to saturation and erosion. Surficial soil water will tend to drain into the pipe, and be carried downgradient or infiltrate to a lower level out the bottom of the pipe. Subsurface drains can be used to improve slope stability and to stabilize berms and drainage structures. Tile underdrains can be used for the same purpose, but are usually more expensive to purchase and install.

| Flumes | References: 16 |
|---|---|

**Objective:**

The objective of using flumes, or channelized flow paths, for runoff is to reduce erosion caused by excess overland flow of stormwater.

**Principle:**

Overland flow of runoff can cause significant erosion and soil loss, especially on slopes and in areas with high topographic relief. Flumes provide a stabilized channel to direct runoff to appropriate areas, thus reducing erosion.

**Description:**

Flumes are open channel or piped constructions that intercept and direct stormwater to appropriate receiving areas. They can be either temporary, for use during construction activities, or permanent fixtures on a site. An example of a temporary flume is a slope drain, which consists of a flexible or rigid pipe that is embedded in a side slope to carry stormwater from the top of the slope to the bottom without eroding the land surface. This type of flume is typically employed on a construction site prior to placement of final drainage structures. An example of a permanent flume is a concrete-lined open channel built into the side of a slope to convey stormwater from the top to the bottom of the slope. This application is often seen along highway shoulders with a significant grade. Runoff flow energy is frequently dissipated at the bottom of open channel flumes by embedding bricks in the concrete slope, or other methods of creating turbulence.

| Waterway and Outlet Protection | References: 16, 19 |
| --- | --- |

**Objective:**

The objective of providing waterway and outlet protection is to minimize erosion in stormwater conveyances by providing stable channels and reducing flow velocities in erosion-prone areas.

**Principle:**

Conveyance of stormwater in channels often results in high velocity flow which can cause erosion and damage to channels and outlet structures. Protection of waterways and structures minimizes both degradation to drainage infrastructure and reduces pollutant loads from suspended particles. Although no water quality treatment is afforded by channel and structure protection, these measures prevent additional degradation to stormwater quality during its transport.

**Description:**

Man-made channels such as drainage ditches can be protected from erosion by lining the channel sides and bottom with a stable material, such as concrete or rip rap (large, erosion-resistant stones placed to form channel sides and bottom). Likewise, stabilization can be provided to natural stream channels by the selective use of similar material. However, discretion must be used in altering natural channels, as it is desirable to preserve natural features such as habitat value as much as possible. Also, the entire reach of many channels does not need stabilization. To limit costs and to promote natural functions of these waterways, only portions of channels subject to erosion from high flow velocity, sharp changes in direction, unstable bed material, etc. should be artificially stabilized.

Erosion and damage to structures can occur when stormwater is discharged from a drainage system at high flow rate or high velocity.' Placing energy dissipating devices in the flow path (introducing turbulence in the flow or placing check dams in the channels to temporarily obstruct flow), or constructing stilling wells at stormwater discharge points reduces runoff flow velocity and subsequent impacts. This can be accomplished through use of paved aprons or spreader structures to disperse flows at discharge points, or by installing rip rap, providing drop structures to allow stormwater to "step down" inclines without traveling a high-grade slope, or other structural means.

### 3.2 Vegetative Practices

The primary objective of vegetative erosion control practices is to provide vegetative cover for soils that may be eroded is left exposed. Vegetation acts to control erosion by reducing the overland flow velocity of runoff, trapping particulate material, preventing the entrainment of soil particles by an interwoven root network, and reducing the physical impacts of rainfall on soil that leads to erosion, by providing a ground cover to deflect the force of falling rain drops.

This objective can be met by either preserving existing vegetation on a site, or by planting desirable vegetation for erosion control, as well as for landscaping purposes. Existing vegetation is often desirable to leave on a site, because the plant community is already established, and the living root mat is well developed. The survival of existing vegetation is relatively well-insured because of the plants' exposure to site conditions, unlike planting new vegetation and hoping that it adapts to local sunlight and water availability.

Vegetation is an ideal means of reducing erosion in Florida. The long growing season and mild winters ensure that a viable plant community will be active all year. Most types of vegetation will help reduce erosion. Grass is very well suited for this purpose because of its homogeneous coverage and thick root structure. However, advantageously located vines, bushes, shrubs, or non-woody ground covers are also desirable. Trees are beneficial also, their canopy reducing the force of falling rain and their roots holding soil in place under most conditions, including stream banks and steep slopes.

The level of effort required for the maintenance of vegetation erosion controls varies with the type of plants used. Natural species will require the least care, possibly only annual pruning. Many common landscape plants may require more care, including watering, fertilization, cutting back or pruning, and application of pesticides. It can be seen that using in-place vegetation can be a considerably less expensive means of controlling erosion than using either structural methods or by using introduced vegetation.

| Preparation of Site for Vegetation | References: 16, 19 |
|---|---|

**Objective:**

The objective of preparing a site for vegetation establishment is to maximize the surviving ratio of plants, when planted.

**Principle:**

If vegetation intended to aid in erosion control or other hydrologic functions is planted in unprepared sites, conditions may not be suitable for its survival and plantings may be unsuccessful. By ensuring that a site has appropriate conditions for plant growth, more effective erosion control can be accomplished.

**Description:**

Site preparation ensures that a site's soil composition and stability, hydrologic features, and other factors important to plant survival are ready for planting to begin. Activities that can apply include site grading to establish surface drainage patterns, soil surface roughening (scarifying), adding topsoil or fertilizer, testing soil for moisture content, fertilization, ensuring that sufficient sunlight is available for the target species, removing nuisance plants, etc. All these items should be accomplished prior to planting to ensure that desirable vegetation becomes established quickly and provides adequate protection against erosion and soil loss.

| Grass Establishment | References: 16, 19 |
|---|---|

**Objective:**

The objective of establishing grass on a site to address water quality of stormwater is to provide a stable ground cover to cover bare soil and reduce erosion and the entrainment of particulates in runoff.

**Principle:**

Bare soil is subject to sediment loss from erosion by stormwater. Grass ground cover provides a stable, cost-effective, easily maintainable means of reducing soil loss through erosion. This is accomplished through a reduction in flow velocity caused by grass stems, and by the root network adding cohesiveness to the soil surface.

**Description:**

Establishing grass on a site can be accomplished in several different ways. Temporary grass cover can be accomplished through scattering of an annual grass such as rye. Permanent grass cover can also be accomplished by seeding. Sod is often used when a stable ground cover is needed immediately. Sometimes, a single row of sod will be located at the edge of an area of bare soil for stability, and the remainder of the site will be seeded. Watering and fertilization is usually necessary to ensure good survival. Also, sod is often used to establish grass on slopes, where seed would tend to wash off in the rain or when watered.

| Mulches | References: 16, 19 |
|---|---|

**Objective:**

The objective of using mulch is to provide an organic layer for soil stabilization or base for grass seed dispersion.

**Principle:**

Grass seed, if cast alone, is subject to removal by wind, water, or other disturbance. Placing a layer of mulch on bare soil supplies an intermediate level of stability until the area is sodded or until the grass seed or ground cover becomes established.

**Description:**

Mulches are shredded organic material that is spread on bare soil to stabilize it, or to serve as an organic base for grass seed or other ground cover. Mulch can be manually spread, distributed mechanically off the back of a truck or wagon, or can be "shot", usually as a slurry of water, mulch, seed, and fertilizer, out of a large diameter spray nozzle. Mulch is a good method, intermediate in cost, effort, and effectiveness between seeding and sodding, of establishing grass on bare soil.

| Other Vegetation | |
|---|---|

**Objective:**

The objective of any vegetative erosion control is to provide stability to soils to reduce soil loss to stormwater through erosion.

**Principle:**

Any type of vegetation tends to add stability to the underlying soils. This results from the above-ground plant slowing the velocity of runoff flow, and by the root structure adding cohesiveness to the soil.

**Description:**

Other types of vegetation stabilization include many forms of ornamental ground cover, preservation of natural vegetation, and landscaping to place plants in the most advantageous location to assist in erosion control and stormwater quality treatment. A variety of plants are available that are well-suited for erosion control, and that provide additional benefits of aesthetics, wildlife habitat, climate control, edible fruits, noise abatement, dust control, site security, and privacy. Candidate species include ground covers, bushes, shrubs, vines, and trees.

## 3.0 Agricultural BMPs Applicable in the Tampa Bay Watershed

Agricultural BMPs applicable in the Tampa Bay watershed were identified using the "BMP Selector" from the Florida Cooperative Extension Service, IFAS, SP-15; the NRCS Field Office Technical Guide; and personal communications and discussions with Dr. Phyllis Gilreath, Cooperative Extension Service, Manatee County, Florida.

The following defines the BMPs identified as being most applicable to the agricultural land uses practices and physical settings in the Tampa Bay watershed. Table 3-1 summarizes the BMPs and identifies the anticipated benefits according to agricultural land use. The anticipated benefits include nitrogen load reduction, pesticide load reduction, erosion control, and water conservation. The major agricultural land use types include row crops, citrus groves, and pasture and livestock. A number of the agricultural BMPs examined offer multiple benefits and can be implemented for more than one agricultural land use.

### NUTRIENT CONTROL BMPs

**Fencing** - Fencing is the dividing or enclosing of land areas with a suitable permanent structure that acts as a barrier for livestock, game, or people. Fencing serves to: subdivide grazing land to permit use of planned grazing systems; exclude livestock or big game from plant communities that cannot withstand grazing; confine livestock or big game on an area; regulate access to areas by people and prevent trespassing; distribute grazing pressures more evenly thereby enhancing the quality of runoff water; and allow deferment periods to be incorporated with brush management practices thereby improving the efficiency of water use.

**Fertigation** - The delivery of fertilizer materials via an irrigation system.

**Irrigation Water Management** - The use of proper irrigation water management involves the determination and control of the rate, amount, and timing of irrigation water application in a planned and efficient manner through use of flow meters and potentiometers. The purpose of irrigation water management is to effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response and to minimize soils erosion, runoff, and fertilizer and pesticide movement, and to protect water quality. In order for the above stated purpose to be achieved, the irrigator of a conservation irrigation system must have the capability and knowledge to: determine when irrigation water should be applied based on the rate of water use by the crop and the stages of plant growth; measure or estimate the amount of water required for each irrigation, including the leaching needs; determine the normal time needed for the soil to absorb the required amount of water and how to detect changes in intake rates; adjust stream size, application rate, or irrigation time to compensate for changes in such factors as intake rate or the amount of water to be applied; recognize erosion caused by irrigation; estimate the amount of irrigation runoff from an area; and evaluate the uniformity of water application.

**Land Absorption Wetland Use** - This practice serves to provide, through use of existing wetland areas, an adequate land absorption area downstream from grazed areas so that soil and plants absorb nutrients and animal wastes.

**Mulching** - Mulching is the practice of applying plant residues, or other suitable materials not produced on the site, to the soil surface. Mulching conserves moisture, prevents surface compaction or crusting, reduces runoff and wind and water erosion, controls weeds, and helps establish plant cover. Mulching is applicable to soils subject to erosion on which low-residue-producing crops are grown, on critical areas and on soils that have a low infiltration rate.

**Nutrient Management** - Nutrient management practices involve the managing of the amount, source, form, placement, and timing of applications of plant nutrients. It may include the management of plant nutrients associated with organic waste, commercial fertilizer, legume crops, and crop residues. Such practices can be applied to all lands to which materials containing plant nutrients are applied. Nutrient management practices serve to supply adequate plant nutrients for optimum (maximum economic) forage and crop yields, to minimize entry of nutrients to surface and ground water, and to maintain or improve the chemical and biological condition of the soil. Proper nutrient management practices reduce the availability of nutrients that could pollute surface or groundwater by managing the application method and amounts of nutrients applied to the soil.

The NRCS Field Office Technical Guide includes several planning considerations for proper nutrient management practices. It should be recognized that several other listed BMPs could be grouped as a nutrient management practice (e.g., waste utilization, soil testing, plant analysis, and timing and placement of fertilizers).

**Rotational Grazing** - Rotational grazing is a system in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years. The rest periods may be throughout the year or during the growing season of key plants. Rotational grazing serves several purposes, including: to maintain existing plant cover or hasten its improvement while properly using the forage of all grazing units; to improve water quality and reduce erosion; to increase grazing efficiency by uniformly using all parts of each grazing unit; to provide adequate forage throughout the grazing season; to improve forage quality and increase production; to enhance wildlife habitat; to promote flexibility in the grazing program and buffer the adverse effects of drought; and to promote energy conservation by using reduced amounts of fossil fuel.

**Shade Areas** - Shade areas serve to lessen the need for animals to enter water for relief from heat by using trees or artificial shelters to provide shade at selected locations. Such practices minimize animal contact with surface waters and thereby serve to protect surface waters from animal waste contamination. This practice may also serve to reduce erosional processes along stream banks due to reduced animal traffic.

**Slow Release Fertilizer** - The use of slow release fertilizers minimizes nitrogen losses from soils prone to leaching. Slow release fertilizer is used somewhat for strawberries and citrus crops in the Tampa Bay watershed.

**Soil Testing and Plant Analysis** - These practices involve testing of soil and plants to avoid overfertilization and subsequent losses of nutrients in runoff water.

**Timing and Placement of Fertilizers** - The proper timing and placement of fertilizers provides for maximum utilization by plants and minimum leaching or movement by surface runoff. The practice works well with drip irrigation systems. Citrus growers use split applications to save fertilizer.

**Waste Management Systems** - These are planned systems in which all necessary components are installed for managing liquid and solid waste, including runoff from concentrated waste areas, such that air, soil, and water resources are not degraded. The purpose of this practice is to manage waste in rural areas such that air, soil, and water resources are not degraded, and to manage waste in order to protect public health and safety. These systems should preclude pollutant discharges to surface or ground water and should recycle waste through soil and plants to the fullest extent practicable. The practice applies where: waste is generated by agricultural production; waste from municipal and industrial treatment plants is used in agricultural production; all practice components necessary to make a complete system are specified; and soil, water, and plant resources are adequate to properly manage waste. These systems may consist of a single component, such as a diversion, or may consist of several components. Examples of components that could be used in a waste management system include fencing, pond sealings or linings, subsurface drains, water storage ponds, waste treatment lagoons, and grassed waterways or outlets.

**Waste Utilization** - Waste utilization is the practice of using agricultural wastes and other wastes on land in an environmentally acceptable manner while maintaining or improving soil and plant resources. Waste utilization is a means to safely use wastes to provide fertility for crop, forage, or fiber production; to improve or maintain soil structure; to prevent erosion and to safeguard water resources. The practice involves the use of wastes for application to crops. Recommended waste application rate guidelines are listed in the NRCS Field Office Technical Guide. This practice may also include recycling of waste solids for animal feed supplement.

**Water Table Management** - Water table management or control is the practice of controlling the water table through proper use of subsurface drains, water control structures, and water conveyance facilities for the efficient removal of drainage water and distribution of irrigation water. The practice improves the soil environment for vegetative growth by regulating the water table to remove excess runoff and subsurface water, facilitate leaching of saline or alkali soil, and regulate or manage ground water for subirrigation. The practice applies where: a high water table exists; topography is relatively smooth and flat; adequate water is available; the benefits of subirrigation, in addition to controlling ground water and surface runoff, justify system installation; soil depth and permeability will permit effective operation of the control system; saline or sodic soil conditions can be maintained of an acceptable level for efficient production of crops; a suitable outlet exists; and improvements for off-site water quality are needed and can be achieved through water table management techniques.

**Water Tolerant Crops** - This practice involves the careful selection of water-tolerant crops for organic soils so higher water tables can be maintained to reduce oxidation and release of nutrients to drainage water.

**Water/Feeder Location** - This practice involves the locating of feeders and watering facilities a reasonable distance from streams and water courses. The practice serves to reduce livestock concentrations, particularly near streams, and to encourage more uniform grazing. Properly locating watering and feeding facilities can improve surface water quality and reduce erosion around stream and creek banks.

## WATER/IRRIGATION BMPs

**Irrigation Water Conveyance** - An irrigation water conveyance consists of a fixed lining of impervious material installed in an existing or newly constructed irrigation field ditch, irrigation canal, or lateral. Irrigation water conveyances are used to prevent waterlogging of land, to maintain water quality, to prevent erosion, and to reduce water loss. The practice is applicable to ditches and canals that serve as integral parts of an irrigation water distribution or conveyance system that has been designed to facilitate the conservative use of soil and water resources on a farm or group of farms.

**Irrigation Water Management** - The use of proper irrigation water management involves the determination and control of the rate, amount, and timing of irrigation water application in a planned and efficient manner through use of flow meters and potentiometers. The purpose of irrigation water management is to effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response and to minimize soils erosion, runoff, and fertilizer and pesticide movement, and to protect water quality. In order for the above stated purpose to be achieved, the irrigator of a conservation irrigation system must have the capability and knowledge to: determine when irrigation water should be applied based on the rate of water use by the crop and the stages of plant growth; measure or estimate the amount of water required for each irrigation, including the leaching needs; determine the normal time needed for the soil to absorb the required amount of water and how to detect changes in intake rates; adjust stream size, application rate, or irrigation time to compensate for changes in such factors as intake rate or the amount of water to be applied; recognize erosion caused by irrigation; estimate the amount of irrigation runoff from an area; and evaluate the uniformity of water application.

**Land Leveling (with Laser)** - Land leveling is the practice of reshaping the surface of the land to be irrigated to planned grades. Land leveling permits uniform and efficient application of irrigation water without causing erosion, loss of water quality, or damage to land by waterlogging, yet at the same time provides for adequate surface or subsurface drainage. Soils should be deep enough so that after leveling work is completed an adequate and usable root zone remains that will produce satisfactory crop production with proper conservation measures. In the Tampa Bay watershed, land leveling is most important for crops utilizing seep irrigation systems.

**Mulching** - Mulching is the practice of applying plant residues, or other suitable materials not produced on the site, to the soil surface. Mulching conserves moisture, prevents surface compaction or crusting, reduces runoff and wind and water erosion, controls weeds, and helps establish plant cover. Mulching is applicable to soils subject to erosion on which low-residue-producing crops are grown, on critical areas and on soils that have a low infiltration rate.

**Pasture and Hayland Management** - Pasture and hayland management involves the proper treatment and use of pastureland and hayland. The practice serves to prolong life of desirable forage species; to maintain or improve the quality and quantity of forage; and to protect the soil and reduce water loss. Pasture and hayland management practices can be used on all pastureland or hayland. An important aspect of these practices focuses on balancing fertilization according to production needs. Most Florida soils need fertilization to produce optimum yields of forage crops. Fertilization programs must consider the production needs and nutrient requirement of the forage crop, as well as the ability of the soil to retain and deliver nutrients and water. Although the NRCS Field Office Technical Guide provides specifications on fertilization of forage crops without the benefit of soil test results, the NRCS highly recommends the use of annual soil testing to assess fertilization requirements.

**Pasture and Hayland Planting** - Pasture and hayland planting practices primarily serve to establish forage plants on erodible soils to reduce runoff and erosion.

**Prescribed Burning** - Prescribed burning is the practice of applying fire to predetermined areas such that the intensity and spread of the fire are controlled. Prescribed burning practices control undesirable vegetation; prepare sites for planting and seedings; control plant diseases; reduce fire hazards; improve wildlife habitat, forage production, and forage quality; and facilitate distribution of grazing and browsing animals.

**Range Seeding** - Range seeding is the practice of establishing adapted plants by seeding on rangeland. Range seeding prevents excessive soil and water loss; produces more forage on rangeland or land converted to range from other uses; and improves the aesthetic quality of the grazing land. This practice is applicable on rangeland, native pasture, grazable woodland, and grazed wildlife land.

**Trickle Irrigation System** - A trickle irrigation system (e.g., spray jet irrigation or drip irrigation) is a planned system in which necessary facilities are installed for efficiently applying water directly to the root zone of plants via small diameter pipes, and by using special applicators (orifices, emitters, porous tubing, perforated pipe) operated under low pressure. The applicators may be placed on or below the ground surface. These systems maintain soil moisture within the range for good plant growth without excessive water loss, erosion, reduction in water quality, or salt accumulation. The design of a trickle irrigation system is based on an evaluation of the site and the expected operating conditions. The soils and topography must be suitable for irrigation of the proposed crops, and the water supply must be sufficient in quantity and quality for the intended crops to be grown. Trickle irrigation is suited to most orchard (or grove) crops and row crops as well as for gardens, flowers, and shrubs in urban settings where small flow rates of water can be used efficiently. According to the NRCS's Technical Guide for agricultural BMPs, the field application efficiency of trickle irrigation systems may reach 90%.

**Water Table Management** - Water table management or control is the practice of controlling the water table through proper use of subsurface drains, water control structures, and water conveyance facilities for the efficient removal of drainage water and distribution of irrigation water. The practice improves the soil environment for vegetative growth by regulating the water table to remove excess runoff and subsurface water, facilitate leaching of saline or alkali soil, and regulate or manage ground water for subirrigation. The practice applies where: a high water table exists; topography is relatively smooth and flat; adequate water is available; the benefits of subirrigation, in addition to controlling ground water and surface runoff, justify system installation; soil depth and permeability will permit effective operation of the control system; saline or sodic soil conditions can be maintained at an acceptable level for efficient production of crops; a suitable outlet exists; and improvements for off-site water quality are needed and can be achieved through water table management techniques.

**Water Tolerant Crops** - This practice involves the careful selection of water-tolerant crops for organic soils so higher water tables can be maintained to reduce oxidation and release of nutrients to drainage water.

## PESTICIDE USE BMPs

**Correct Pesticide Application** - Correct pesticide application practices involve the responsible use of pesticides to minimize pesticide movement from the field where applications are made. Practices may include the spraying of pesticides when conditions for drift are minimal, mixing the pesticide properly with soil when specified, and avoiding applications when heavy rain is forecast.

**Correct Pesticide Container Disposal** - Correct pesticide container disposal practices refer to the use of the accepted methods for pesticide container disposal (such as those specified on the pesticide label).

**Cultural Control of Pests** - The cultural control of pests refers to using cultural practices, such as elimination of host sites and adjustment of planting schedules (i.e., crop rotation), to partly substitute for pesticides. The use of this practice should reduce the amount of pesticides introduced into the environment and thus protect surface and ground water quality from pesticide contamination.

**Integrated Pest Management (IPM)** - IPM practices encompass a variety of techniques to minimize or preclude the use of pesticides on agricultural crops. Practices include the use of crop rotation to reduce buildup of insects, the use of alternate control methods such as cover crops to foster populations of beneficial insects, the determination of economic pest thresholds, the adjusting of planting and harvest periods, and the use of field scouting. Additional components that may be part of an IPM program include the use of natural enemies and pheromones. These later components are primarily used in ornamental horticulture.

**Irrigation Water Management** - The use of proper irrigation water management involves the determination and control of the rate, amount, and timing of irrigation water application in a planned and efficient manner through use of flow meters and potentiometers. The purpose of irrigation water management is to effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response and to minimize soils erosion, runoff, and fertilizer and pesticide movement, and to protect water quality. In order for the above stated purpose to be achieved, the irrigator of a conservation irrigation system must have the capability and knowledge to: determine when irrigation water should be applied based on the rate of water use by the crop and the stages of plant growth; measure or estimate the amount of water required for each irrigation, including the leaching needs; determine the normal time needed for the soil to absorb the required amount of water and how to detect changes in intake rates; adjust stream size, application rate, or irrigation time to compensate for changes in such factors as intake rate or the amount of water to be applied; recognize erosion caused by irrigation; estimate the amount of irrigation runoff from an area; and evaluate the uniformity of water application.

**Pesticide Selection** - Proper pesticide selection practices refer to the selection of pesticides which are least toxic, persistent, soluble, and volatile as feasible for worker safety and protection of environment.

## EROSION CONTROL BMPs

**Conservation Cropping System** - Conservation cropping is a system of growing crops in combination with needed cultural and management measures to improve the soil and protect it during periods when erosion occurs. Conservation cropping practices provide vegetative cover (often weed fallow) between crop seasons. The practice may include cover cropping and crop rotation.

**Critical Area Planting** - Critical area planting is the planting of vegetation such as trees, shrubs, grasses or legumes on critical areas. Critical area planting serves to stabilize the soil, reduce erosion and runoff to downstream areas, improve wildlife habitat, and enhance natural beauty. Applicable areas include sediment-producing, highly erodible or severely eroded areas, such as dams, dikes, ditches, mine spoil, levees, cuts, fills, surface-mined areas, and denuded or gullied areas where vegetation is difficult to establish with usual seeding or planting methods.

The NRCS Field Office Technical Guide includes detailed specifications for five categories of critical area plantings; they include:

342-I Permanent Seedings;
342-II Temporary Seedings;
342-III Sod;
342IV With Ground Cover, Vines, Shrubs and Other Plants; and
342-V On Coastal Dune Areas.

**Deferred Grazing** - Deferred grazing practices postpone grazing for a prescribed period to improve vegetative conditions and reduce soil loss. Deferred grazing promotes natural revegetation by improving the health of the forage stand and permitting desirable plants to produce seed. Deferred grazing also serves to provide a feed reserve for fall and winter grazing or emergency use, reduce soil loss and improve water quality, and maintain or improve wildlife habitat. Deferred grazing practices which employ planned deferment periods can be applied to all rangeland, native pasture, grazable woodland, and grazed wildlife land. Planned deferment periods should be based on: the type of plants managed for, timing of "green-up" and active growth period, and plant vigor; the vigor and growth habits of the key forage species; weather and growing conditions; and the land user's goals. The planned deferment, however, must not cause overuse or have an adverse impact on the rest of the operating unit.

**Fencing** - Fencing is the dividing or enclosing of land areas with a suitable permanent structure that acts as a barrier for livestock, game, or people. Fencing serves to: subdivide grazing land to permit use of planned grazing systems; exclude livestock or big game from plant communities that cannot withstand grazing; confine livestock or big game on an area; regulate access to areas by people and prevent trespassing; distribute grazing pressures more evenly thereby enhancing the quality of runoff water; and allow deferment periods to be incorporated with brush management practices thereby improving the efficiency of water use.

**Field Windbreak** - A field windbreak is a strip or belt of trees (e.g., cedar tree wind blocks for potato farms) established in or adjacent to a field. Field windbreaks serve to reduce soil erosion from wind; conserve moisture; protect crops, groves, livestock, and wildlife; and increase the natural beauty of an area. Field windbreaks can be grown in or around open fields needing protection against wind damage, or where strips of trees or shrubs increase the natural beauty of an area or provide food and cover for wildlife.

**Grassed Waterways or Outlet** - This BMP includes natural or constructed channels or outlets that are shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff. This BMP applies to natural or constructed channels that are to be established to vegetation and used for water disposal. Grassed waterways serve to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding, and to improve water quality. This practice is applicable to all sites where added capacity, vegetative protection, or both are required to control erosion resulting from concentrated runoff and where such control can be achieved by using this practice alone or combined with other conservation practices. The practice should not be used where its construction would destroy important woody wildlife cover and where the present watercourse is not seriously eroding.

**Irrigation Water Conveyance** - An irrigation water conveyance consists of a fixed lining of impervious material installed in an existing or newly constructed irrigation field ditch, irrigation canal, or lateral. Irrigation water conveyances are used to prevent waterlogging of land, to maintain water quality, to prevent erosion, and to reduce water loss. The practice is applicable to ditches and canals that serve as integral parts of an irrigation water distribution or conveyance system that has been designed to facilitate the conservative use of soil and water resources on a farm or group of farms.

**Irrigation Water Management** - The use of proper irrigation water management involves the determination and control of the rate, amount, and timing of irrigation water application in a planned and efficient manner through use of flow meters and potentiometers. The purpose of irrigation water management is to effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response and to minimize soils erosion, runoff, and fertilizer and pesticide movement, and to protect water quality. In order for the above stated purpose to be achieved, the irrigator of a conservation irrigation system must have the capability and knowledge to: determine when irrigation water should be applied based on the rate of water use by the crop and the stages of plant growth; measure or estimate the amount of water required for each irrigation, including the leaching needs; determine the normal time needed for the soil to absorb the required amount of water and how to detect changes in intake rates; adjust stream size, application rate, or irrigation time to compensate for changes in such factors as intake rate or the amount of water to be applied; recognize erosion caused by irrigation; estimate the amount of irrigation runoff from an area; and evaluate the uniformity of water application.

**Land Leveling (with Laser)** - Land leveling is the practice of reshaping the surface of the land to be irrigated to planned grades. Land leveling permits uniform and efficient application of irrigation water without causing erosion, loss of water quality, or damage to land by waterlogging, yet at the same time provides for adequate surface or subsurface drainage. Soils should be deep enough so that after leveling work is completed an adequate and usable root zone remains that will produce satisfactory crop production with proper conservation measures. In the Tampa Bay watershed, land leveling is most important for crops utilizing seep irrigation systems.

**Mulching** - Mulching is the practice of applying plant residues, or other suitable materials not produced on the site, to the soil surface. Mulching conserves moisture, prevents surface compaction or crusting, reduces runoff and wind and water erosion, controls weeds, and helps establish plant cover. Mulching is applicable to soils subject to erosion on which low-residue-producing crops are grown, on critical areas and on soils that have a low infiltration rate.

**Pasture and Hayland Management** - Pasture and hayland management involves the proper treatment and use of pastureland and hayland. The practice serves to prolong life of desirable forage species; to maintain or improve the quality and quantity of forage; and to protect the soil and reduce water loss. Pasture and hayland management practices can be used on all pastureland or hayland. An important aspect of these practices focuses on balancing fertilization according to production needs. Most Florida soils need fertilization to produce optimum yields of forage crops. Fertilization programs must consider the production needs and nutrient requirement of the forage crop, as well as the ability of the soil to retain and deliver nutrients and water. Although the NRCS Field Office Technical Guide provides specifications on fertilization of forage crops without the benefit of soil test results, the NRCS highly recommends the use of annual soil testing to assess fertilization requirements.

**Pasture and Hayland Planting** - Pasture and hayland planting practices primarily serve to establish forage plants on erodible soils to reduce runoff and erosion.

**Prescribed Burning** - Prescribed burning is the practice of applying fire to predetermined areas such that the intensity and spread of the fire are controlled. Prescribed burning practices control undesirable vegetation; prepare sites for planting and seedings; control plant diseases; reduce fire hazards; improve wildlife habitat, forage production, and forage quality; and facilitate distribution of grazing and browsing animals.

**Proper Grazing Use** - Proper grazing use is the practice of grazing at an intensity which will maintain enough vegetative cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation. This practice serves to increase the vigor and reproduction of key plants; accumulate litter and mulch necessary to reduce erosion and sedimentation and improve water quality; improve or maintain the condition of existing vegetation; increase forage production; maintain natural beauty; reduce hazard of wildfire; and improve or maintain wildlife habitat. The practice is applicable on all rangeland, native pasture, and grazed wildlife land.

**Range Seeding** - Range seeding is the practice of establishing adapted plants by seeding on rangeland. Range seeding prevents excessive soil and water loss; produces more forage on rangeland or land converted to range from other uses; and improves the aesthetic quality of the grazing land. This practice is applicable on rangeland, native pasture, grazable woodland, and grazed wildlife land.

**Rotational Grazing** - Rotational grazing is a system in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years. The rest periods may be throughout the year or during the growing season of key plants. Rotational grazing serves several purposes, including: to maintain existing plant cover or hasten its improvement while properly using the forage of all grazing units; to improve water quality and reduce erosion; to increase grazing efficiency by uniformly using all parts of each grazing unit; to provide adequate forage throughout the grazing season; to improve forage quality and increase production; to enhance wildlife habitat; and to promote flexibility in the grazing program and buffer the adverse effects of drought.

**Runoff Management System** - This is a system for controlling excess runoff caused by construction operations at development sites, changes in land use, or other land disturbances such as the preparation of a field for a new crop. Proper runoff management serves to regulate the rate and amount of runoff and sediment from development sites during and after construction operations to minimize undesirable effects such as flooding, erosion, and sedimentation. Runoff management systems should be used to control runoff, erosion, and sedimentation to compensate for increased peak discharges and erosion resulting from construction activities. The practice involves the planning, design, installation, operation, and maintenance of runoff management systems, including adequate outlet facilities and components necessary for adequate management of storm runoff. Components may include dams, excavated ponds, exfiltration trenches, parking lot storage, rooftop storage, and underground tanks.

**Shade Areas** - Shade areas serve to lessen the need for animals to enter water for relief from heat by using trees or artificial shelters to provide shade at selected locations. Such practices minimize animal contact with surface waters and thereby serve to protect surface waters from animal waste contamination. This practice may also serve to reduce erosional processes along stream banks due to reduced animal traffic.

**Water/Feeder Location** - This practice involves the locating of feeders and watering facilities a reasonable distance from streams and water courses. The practice serves to reduce livestock concentrations, particularly near streams, and to encourage more uniform grazing. Properly locating watering and feeding facilities can improve surface water quality and reduce erosion around stream and creek banks.

**Woodland Site Management** - Woodland site management is the practice of managing soils and vegetation in woodland areas to encourage rapid growth of desirable trees in order to reduce soil erosion runoff.

**Table 3-1. Agricultural BMPs applicable in the Tampa Bay watershed including the problems addressed by agricultural land use type.**

| PROBLEM → | NITROGEN LOADING | | | WATER USE/ IRRIGATION | | | PESTICIDE USE | | | EROSION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LAND USE TYPE →** RC= Row Crop CG=Citrus Grove P/L=Pasture/Livestock | RC | CG | P/L | RC | CG | P/L | RC | CG | P/L | RC | CG | P/L |
| **BMP** | | | | | | | | | | | | |
| Conservation Cropping System | | | | | | | | | | X | | |
| Correct Pesticide Application | | | | | | | X | X | | | | |
| Correct Pesticide Container Disposal | | | | | | | X | X | | | | |
| Critical Area Planting | | | | | | | | | | X | X | X |
| Cultural Control of Pests | | | | | | | X | X | | X | | |
| Deferred Grazing | | | | | | | | | | | | X |
| Fencing | | | X | | | | | | | | | X |
| Fertigation | X | X | | X | X | | | | | | | |
| Field Windbreak | | | | | | | | | | X | | |
| Grassed Waterways or Outlet | | | X | | | | | | | | | X |
| Integrated Pest Management | | | | | | | X | X | X | | | |
| Irrigation Water Conveyances | | | | X | X | | | | | X | X | |
| Irrigation Water Management | X | X | | X | X | | X | X | | X | X | |
| Land Absorption/Wetland Use | | | X | | | | | | | | | |
| Land Leveling (with Laser) | | | | X | | | | | | | | |
| Mulching | X | | | X | | | | | | X | | |
| Nutrient Management | X | X | X | | | | | | | | | |
| Pasture & Hayland Management | | | X | | | X | | | X | | | X |
| Pasture and Hayland Planting | | | X | | | X | | | X | | | X |
| Pesticide Selection | | | | | | | X | X | | | | |
| Prescribed Burning | | | | | | X | | | | | | X |
| Proper Grazing Use | | | | | | | | | | | | X |
| Range Seeding | | | | | | X | | | | | | X |
| Resistant Crop Varieties | | | | | | | X | X | | | | |
| Rotational Grazing | | | X | | | | | | | | | X |
| Runoff Management System | X | X | X | X | X | X | X | | | X | X | X |
| Shade Areas | | | X | | | | | | | | | X |

**Table 3-1. Agricultural BMPs applicable in the Tampa Bay watershed including the problems addressed by agricultural land use type.**

| PROBLEM → | NITROGEN LOADING | | | WATER USE/ IRRIGATION | | | PESTICIDE USE | | | EROSION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAND USE TYPE →<br>RC= Row Crop<br>CG=Citrus Grove<br>P/L=Pasture/Livestock | RC | CG | P/L | RC | CG | P/L | RC | CG | P/L | RC | CG | P/L |
| Slow Release Fertilizer | X | X | X | | | | | | | | | |
| Soil Testing & Plant Analysis | X | X | X | | | | | | | | | |
| Timing & Placement of Fertilizers | X | X | X | | | | | | | | | |
| Trickle Irrigation System | | | | X | X | | | | | | | |
| Waste Management System | | | X | | | | | | | | | |
| Waste Utilization | | | X | | | | | | | | | |
| Water Table Management | | | | X | X | | | | | | | |
| Water Tolerant Crops | | | | X | X | X | | | | | | |
| Water/Feeder Location | | | X | | | | | | | | | X |
| Woodland Site Management | | | | | | | | | | | | X |

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# APPENDIX B

## End-of-pipe Retrofits to Existing Structures

Baffle Box

Baffle boxes provide an end of pipe treatment and are principally designed for sediment removal, but also remove floating debris. They are made out of concrete or fiberglass and can be constructed in line or at the end of existing storm drainpipes. The boxes are typically 10-15 feet long, 6-8 feet high and are generally 2 feet wider than the pipe. The box is divided into two or three chambers by weirs. A manhole is placed over each chamber for cleaning access with vacuum trucks. Trash screens and skimmers are placed to trap floating debris. Baffle boxes can be precast for pipes up to 48 inches, but for pipes greater than 48 inches require pouring in place which is more time consuming and expensive. The installation costs average between $20,000 to $30,000, depending on utilities to be relocated. Studies on scale models have shown that for velocities up to 6 feet/second, baffle boxed have a removal efficiency of 90 percent for coarse sand or sandy clay and 28 percent for finer than clay and silt sized fraction. Also, the removal efficiency increases with the depth of the chambers but so does the time between cleanouts.

Grate Inlet Baskets

A grate inlet baskets is a trash-can like box made out of fiberglass, which is placed inside a grate inlet to trap sediments and floating debris. A stainless steel filter screen traps sediments and floating debris. In addition, the basket contains an absorbent pad to remove oils, grease and other hydrocarbon from the stormwater passing through and also serves as a skimmer to remove floating debris. The Grate Inlet Baskets are custom designed for each inlet and are easy to install and clean.

Curb Inlet Baskets

Curb Inlet Baskets are made out of fiberglass or corrosion-resistant material and fits inside curb inlets to trap floating debris. The baskets are located under a manhole cover for easy removal and cleaning without human entry into confined spaces. These units can be transferred to other location if no longer required and can also be custom designed to fit various curb inlets.

Grate and Curb Protectors

These are simple screens that are constructed of fiberglass or non-corrosive material. The grate protector is like an inverted trash can placed over the grate inlets and is effective in collecting floating trash and sediments. It can be used temporarily during construction of developments such as sub-divisions, shopping centers, industrial parks, highway construction etc. Very limited maintenance is required and this can be left in place for long periods. The curb protector, like the grate protector prevents floating trash, grass clipping and sediments from entering curb inlets. They are easy to install and can be designed to accommodate flow through of the runoff to minimize flooding.

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