STORMWATER MANAGEMENT

Produced and Distributed
By

PDH Now, LLC
7100 Driftwood Dr.
Farmington, NM 87402

STORMWATER MANAGEMENT

TABLE OF CONTENTS

STORMWATER MANAGEMENT

I. EVOLUTION OF STORMWATER MANAGEMENT

A. *Purpose*

The purpose of this course is to familiarize practitioners with the fundamental issues surrounding stormwater management. It provides a general overview with some issues described in more detail, and relates to Florida specifically where appropriate. The subject of stormwater management is quite broad and involves other regulatory and engineering concerns, so when needed, the practitioner is referred to other sources where more detailed information and requirements may be found.

B. *Background*

Throughout the ages, humans have attempted, with much success, to harness the benefits of stormwater with its natural cleansing and groundwater restorative ability, and prevent the damage that can result from uncontrolled flows and flooding. These efforts must be balanced to have water available during droughts and be able to shed the water from the land quickly during times of heavy rainfall events. This requires an extensive understanding of both the existing natural systems of hydrology and hydraulics and the stormwater management infrastructure and other enhancements that must be conceptualized, planned, designed, constructed, and maintained. All these efforts must occur within the given political, social, and economic constraints surrounding the watershed of concern.

Rapid urbanization impacts natural water transport and storage systems and affects water quality. As an area develops, undisturbed pervious surfaces become impervious due to the construction of parking lots, buildings, homes, streets, and other structures. This increase in impervious surfaces results in increased stormwater runoff, which is the water that flows over the land during and immediately after storm events. The increase in stormwater runoff disrupts the natural balance of physical, chemical, and biological processes. It causes pollution in natural systems and results in soil erosion that creates damage downstream. It reduces the infiltration of water into the ground. In addition, the increase in runoff discharging through existing drainage systems may cause flooding.

In the past, conveying water off-site in the shortest time possible was a standard measure for flood protection. Today, more emphasis is being placed on the environmental impacts and effects of drainage systems and urbanization in general. Control of peak flows or volumes, runoff retention and detention for water quality treatment and groundwater recharge, limiting impacts of development, control elevations for surface waters, and flood control are all issues that must be addressed regarding stormwater management.

Communities have implemented management practices for the development and redevelopment of projects to ensure that peak stormwater discharge rates, volumes, and pollution loads leaving a site are minimized without compromising flood protection. This can be achieved through stormwater management plans that provide for surface water drainage, flood protection, erosion and sediment control, aesthetic enhancement, recreational opportunities, reuse of water resources, and the reduction of pollutants through stormwater best management practices (BMPs).

The watershed management guidelines, or “master drainage planning” approach, usually dictates the requirements for stormwater management for a given area. In Florida, information on these requirements can be obtained from the State’s regional water management districts, the Department of Community Affairs, counties, municipalities and the Florida Department of Environmental Protection.

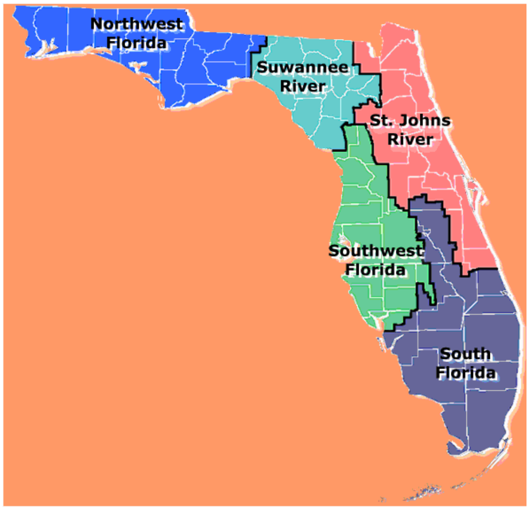


Figure 1. Florida Water Management Districts

Objectives for stormwater management include:

- Prevent flooding (flood control)
- Reduce loss of soil and land to erosion and improve economic performance of agriculture.
- Provide storage of water for continual supply of water for economic and environmental benefits.
- Protect both surface and groundwater quality.
- Maintain a hydrologic balance such that the volume of yearly discharge and recharge matches preconditions. This will maintain or improve groundwater recharge as well as protect historical minimum flows and levels in streams, lakes, and ecosystems.

Limitations for stormwater management include:

- Cost
- Site feasibility
- Environmental impact
- Potential reuse

- Floodplains and wetlands
- Labor and maintenance
- Institutional preferences

General Rules of Thumb

- It is generally more efficient and cost effective to prevent problems rather than correct the problems after the fact.
- Every piece of land is part of a larger watershed.
- Design of a stormwater management system should mimic (and use) the features and functions of the natural drainage system which is largely capital, energy, and maintenance free.
- In general the volume, rate, timing, and pollutant load of stormwater runoff after development should closely approximate the conditions before development.
- Maximize on-site storage of stormwater.
- To maintain water quality, stormwater should generally not be discharged directly to surface or ground waters.
- Stormwater management systems (especially those emphasizing vegetative practices) should be planned, constructed, and stabilized in advance of the facilities that will discharge to them.
- Stormwater management systems must be designed beginning with the outlet or point of outflow from the project.
- Where possible, design and construct the components of a stormwater management system “on the contour” following the topography of the site.
- Stormwater is an important resource that should not be casually discarded but used to replenish water resources.
- Where practical, multiple use temporary storage basins should be considered for an integral component of the stormwater management system.
- Consider designing storage areas with sinuous shorelines to maximize vegetation and length of travel for stormwater.
- Vegetated buffer strips should be retained in their natural state or created along the banks of water bodies.
- All stormwater management systems must receive regular inspection and maintenance.

II. REGULATORY ASPECTS OF STORMWATER MANAGEMENT

Stormwater management regulations in Florida have evolved over time. The Clean Water Act of 1972 was the first federal legislation to address pollution caused by point source discharges of urban stormwater. In Florida during the years that followed, studies showed that stormwater was the primary source of pollutant loading to state surface waters. The Act also identified the need to protect wetlands

Amendments to the Clean Water Act in 1987 specified a process for controlling urban stormwater pollution. It also reemphasized the need for control of nonpoint source pollution. In March 2003, the Act was further amended to require stormwater permits for smaller urbanized areas, industrial operations, and construction sites greater than 1 acre. Section 319 of this Act required states to identify water bodies in which their Section 208 Plan and programs were unsuccessful in controlling pollutants. State's plans were required to identify and categorize sources of pollutants and to describe regulatory or nonregulatory control methods.

Section 404 of the Clean Water Act established a regulatory program for the disposal of dredged or fill materials in the waters and wetlands of the United States. This section is regulated by the U.S. Army Corps of Engineers with EPA oversight. Much debate and litigation has occurred over what constitutes "waters and wetlands of the United States." The following definition is used to administer the Section 404 permit program:

"...those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."

It is important to understand that States can impose more stringent requirements than Federal Rules. Frequently, special habitats and water bodies of concern receive increased scrutiny and regulation. The practitioner would be wise to consult the local permitting authorities for applicable requirements for a specific project's location. Additional BMPs are often specified, and they will be detailed later in this document.

Applicable Florida rules include the State's Water Management Districts' Management and Storage of Surface Waters" and "Environmental Resource Protection" rules and permitting programs. Chapter 62-40.432, FAC, includes the goals, policies and institutional framework for the state's stormwater management program.

The state's stormwater management program is outlined in three sections of Chapter 403, F.S.

- Section 403.0891, "State, regional, and local stormwater management plans and programs.
- Section 403.0893 - "Stormwater funding, dedicated funds for stormwater management," authorizes local governments to create stormwater utilities and stormwater management system benefit areas.
- Section 403.0896 - "Training and assistance for stormwater management system personnel

The Florida Stormwater Rule, Chapter 62- 25, F.A.C., is specifically designed to “prevent pollution of state waters by stormwater discharges.” Currently, DEP 62-25, F.A.C. only applies in NW Florida. Other parts of Florida are covered by water management districts that have developed their own programs. A brief overview of this is as follows:

- SRWMD - 40B-4, F.A.C.
- SJRWMD - 40C-4, 40, 42, F.A.C.
- SWFWMD - 40D-4, 40E-40 F.A.C.
- SFWMD - 40E-4, 40E-40 F.A.C.

For example, the following is an abbreviated compilation of the performance criteria outlined within the St. Johns River Water Management District Applicant's Handbook, with references to the corresponding sections for each item.

I. **Peak Discharge:** Post-development peak rate of discharge must not exceed pre-development peak rate of discharge for a 24-hour duration storm with certain storm frequencies.
II. **Volume:** Post-development volume of direct runoff must not exceed the pre-development volume of direct runoff for a 4-day design storm with storm frequencies as specified under Peak Discharge.
III. **Storage and Conveyance**
    A. A system may not cause a net reduction in flood storage within a 10 year floodplain.
    B. A system may not cause a reduction of flood conveyance capabilities within a floodway.
IV. **Low Flow and Base Flow Maintenance**
    A. System will be designed to discharge the off-site pre-development 5-year, 30-day historical low flow.
    B. System will not cause the ground water table to decline more than three feet lower than the average dry season low water table or at any location, more than five feet lower than the average dry season low water table.
    C. System will not cause the ground water table to be lowered to a level that would drain adjacent surface water bodies below a minimum level established by the Governing Board.
V. **Environmental Considerations**
    A. No adverse impact to off-site aquatic-dependent species.
    B. No water quality degradation below Chapter 62.302, 62-4, F.A.C., standards.
    C. Compliance with Chapter 62-25, F.A.C., for quality of water discharged off-site.

Regulatory and generally accepted criteria for design, operation, and maintenance

Generally a site is evaluated for several criteria. The total area of the site is used, the amount of impervious area is specified, minimum site elevations are established for roads and parking, and for floors. For example, road elevations may be set at or above the 10-year storm event flood level, the stormwater management system design may use a 25-year storm event for calculations, and finished floor elevations for housing and business may be set at or above the 100-year storm event.

Other information required includes soil information, groundwater table elevations, and receiving water body flow and quality criteria.

Requirements, such as retaining the first 1" or more of runoff for a site, or not exceeding a discharge level for the site, will be specified by the local permitting authorities.

Typically, stormwater retention or detention areas will be designed and stage-storage type relationships will be calculated, along with a discharge control structure that allows the system to gradually release flows and allow the system to return to its initial state.

Floodplain regulation and National Flood Insurance Program (NFIP)

Floodplain Regulation - Floodplains are low areas adjacent to streams, lakes, and oceans that are subject to flooding once every 100 years. The definition of a "100 year flood event" is, on average, a flood event that will occur once every 100 years. Special rules apply to areas located within designated floodplain boundaries, which are typically set at the 100-year flood event. The National Flood Insurance Program may provide assistance for such areas to obtain needed insurance, but also may restrict availability, thereby inhibiting development of such areas. Many local governments have taken steps to participate in this program and work with developers and others to minimize potential losses.

Section 404 Permits

Section 404 Permit Requirements – The Federal Water Pollution Control Act, Section 404 as amended, prohibits the discharge of dredged or fill materials into the waters of the United States, including wetlands, unless a permit is acquired from the Corps of Engineers. For applicable Federal Regulations, refer to Code of Federal Regulations, 33 CFR Parts 320 – 330 and 40 CFR Part 230.

State Rules - Wetlands are an important consideration for many projects and the State of Florida.

Other important considerations for any stormwater management system include examination of the type of land use, percent imperviousness, allowable discharge, wetland and other surface water impacts and proposed mitigation, control elevations, and sources of water supply and detention/retention volumes.

III. STORMWATER QUANTITY AND QUALITY MANAGEMENT ISSUES

A. *Hydrology*

- Hydrology involves the study of the properties and behavior of water in the environment, specifically on, under and over the earth's surface.
- Predicting peak rates of flows and volume control are important for design of stormwater management systems.
- Rainfall excess describes the volume of water from rainfall that does not infiltrate and may contribute to runoff.
- Runoff is the rate of flow of stormwater from a site.

i. Hydrologic cycle

The hydrologic ground cycle describes the continual water balance that exists in nature, where water falls to earth, is taken up by plants and animals, evaporates back into the atmosphere or infiltrates into the ground.

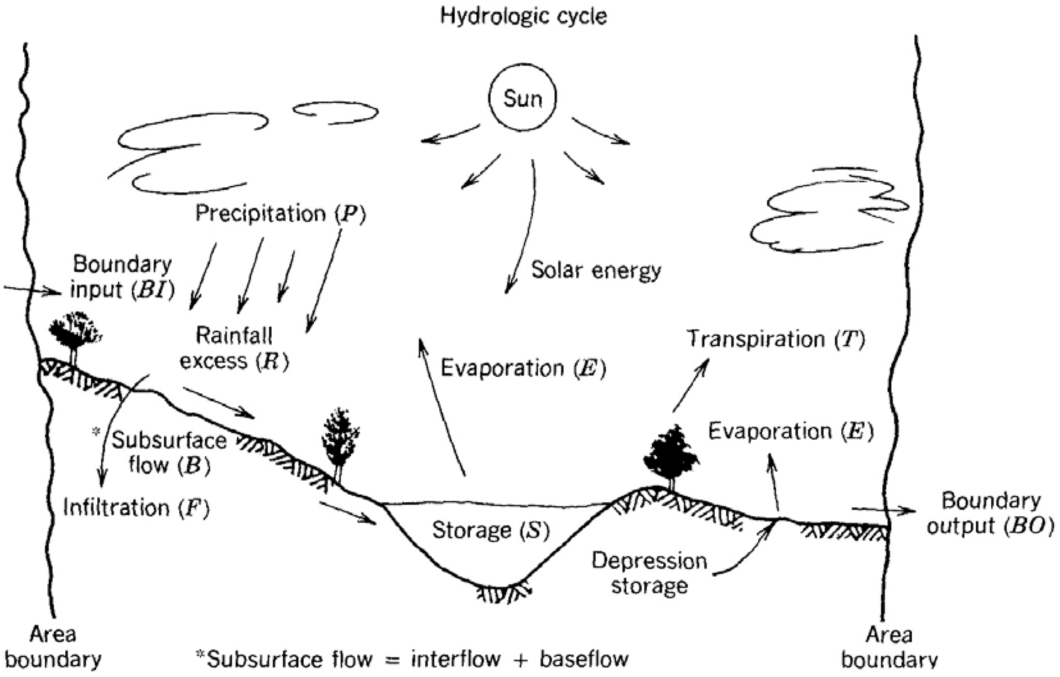
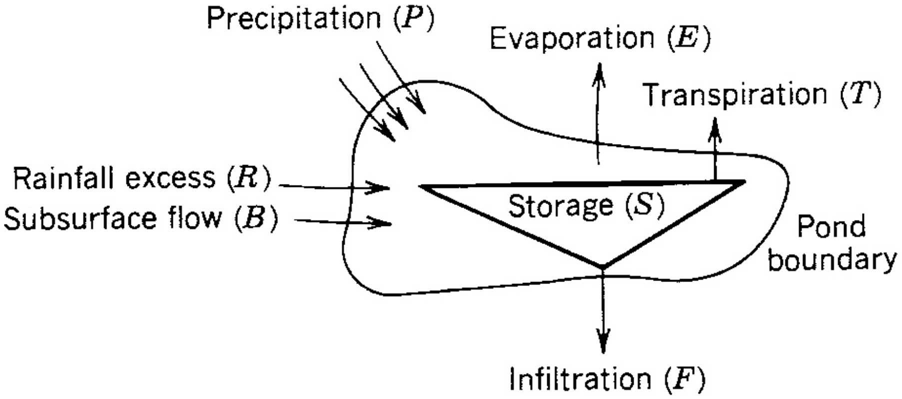


Figure 2. Hydrologic Cycle

(Adapted from Hydrology – Water Quantity and Quality Control, 2nd Ed., Wanielista, 1997.)

A water budget is of concern for engineers. This is when the amounts of water are quantified within a fixed boundary. This calculation involves precipitation, evaporation, transpiration, infiltration, and surface and groundwater flows to mention the more commonly required information. It basically involves the initial storage, adding the inputs, subtracting the outputs, which gives the final storage.



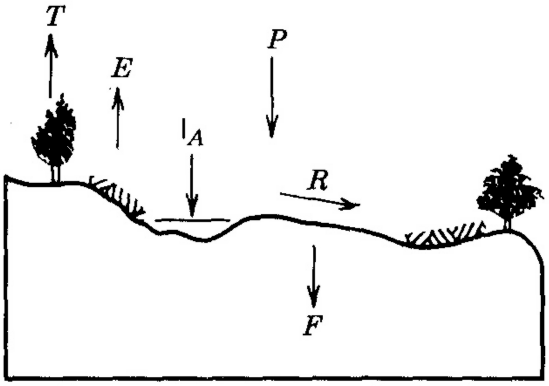
The mass balance equation is as follows:

Inputs – Outputs = Change in Storage

$P + R + B - F - E - T = \Delta S$

Where P = Precipitation
R = Rainfall Excess
B = Subsurface Flow
F = Infiltration
E = Evaporation
T = Transpiration
S = Storage

The following represents how these factors are interpreted for a given site:



Therefore, the equation can be written to calculate the rainfall excess where:

Rainfall Excess = Precipitation – Outputs

$R = P - E - T - F - I_A$

Where I_A = Initial Abstraction

Also, another simplified formula that may be used is:

$R = C \times P$

Where C = dimensionless runoff coefficient and $0 \leq C \leq 1$ and it is referred to as the runoff coefficient, and C represents the ratio of rainfall excess to precipitation.

The following is an example of how a typical storage of runoff in a wet detention pond can increase on-site storage of precipitation and attenuate the peak flow rate from a given site where the 1st inch is retained on-site.

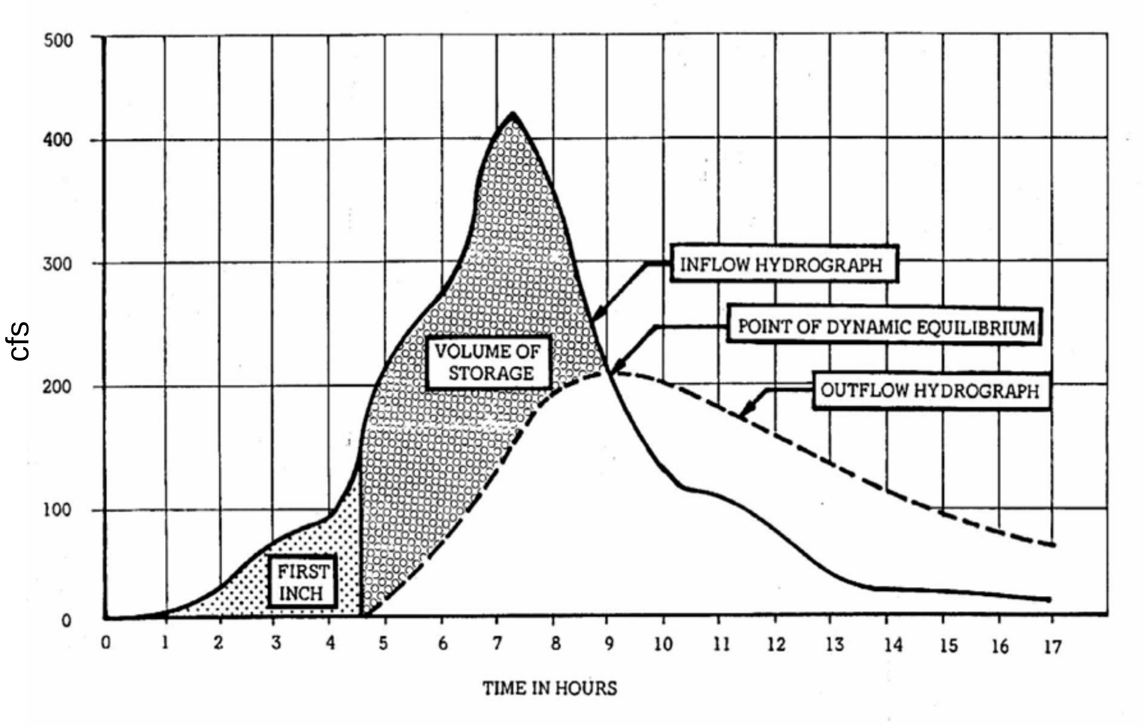


Figure 3. Inflow and Outflow Hydrographs

ii. Rainfall characteristics

Rainfall volumes and intensity-duration-frequency curves and confidence intervals

It is important to be aware of the intensity-duration-frequency (IDF) relationship for a given design storm with a specific return period. The following graph represents this relationship for the city of Jacksonville, Florida. Note that as rainfall intensity goes down, the time duration increases. The volume of rainfall can be calculated by the average intensity multiplied by the duration. A specific IDF curve must be used for a specific project location.

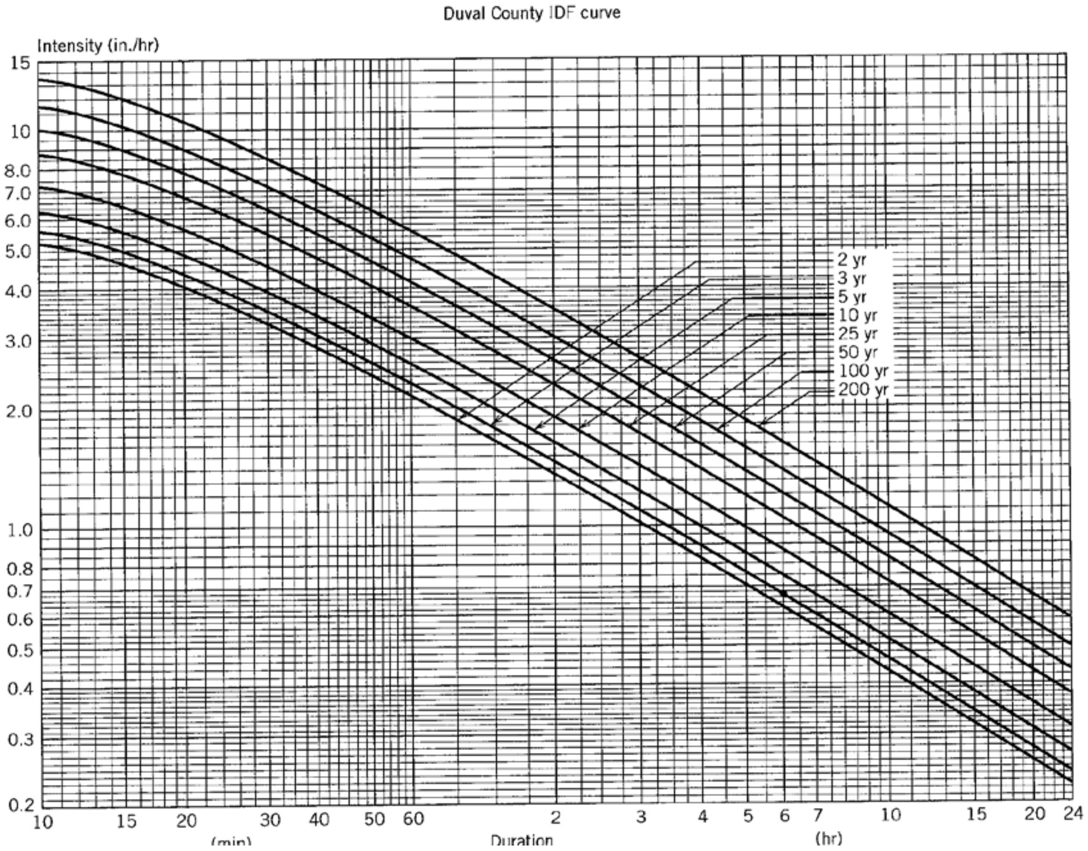


Figure 4. IDF curve for Jacksonville, Florida

Statistical considerations, such as exceedence probability

The return-period for a given storm event is an important consideration when designing a stormwater management system. The Recurrence Interval (T_r) is the average interval of time within which an event will be equaled or exceeded. Therefore the probability of an event occurring during a given year can be expressed as $1/T_r$

The probability (R) that an event (x) will occur at least once (one or more times) in (n) time periods is described as follows:

$$R = \sum_{x=1}^{n} Pr(x;n,p) = 1-(1-p)^n$$

where

x = 0,1,2,3…
n = time period (# of years)
p = probability of each occurrence

For example, a 1 in 20-year storm event would have a 1/20 or 5% chance (p=0.05) of occurring in any given year. For a 3-year period, the probability of at least 1 event greater than or equal to the 20-year event occurring is $1-(1-.05)^3 = .14$, or 14%.

Also, a 1 in 100-year storm event has a .01, or 1%, chance of occurring in any given year. Over a period of 50 years, the chance of a 100-year storm event or greater occurring at least once is $R = 1-(1-.01)^{50}$, or 39%.

It has been shown that, in Florida, 90% of storm events are 1" or less provided they are from meteorologically separate events with a minimum of a 4-hour interevent dry period. This is the reasoning behind designing a typical stormwater management system to capture at least the 1st inch of rainfall. This rainfall event and all those events less than 1 inch have a cumulative yearly volume of discharge equal to approximately 80% of the yearly total. This is the basis for the State wide pollution control design event criteria.

B. *Hydraulics*

i. Hydrographs and flow rate attenuation

- Rational method—The rational method involves the assumption that peak discharge is directly related to the rainfall intensity. The formula is typically written as follows:

  $Q = C\ i\ A$

  Where

Q = peak discharge, typically expressed in cubic feet per second (cfs)
C = is a non-dimensional runoff coefficient, where $0 \leq C \leq 1$, for a given watershed or site
i = average rainfall intensity for a given storm event (inches/hour)
A = contributing area of the watershed where the rain falls at the given intensity, which is typically expressed in acres.

Note: For unit conversion, the following relation is can be used:

1.000 acre-inch/hour = 1.008 cfs

Other factors of concern that a practitioner must consider include soil storage considerations, infiltration capabilities, and antecedent moisture conditions. After development of a site, compaction and impervious areas will lessen the ability of the site to store water within the soil.

Soil Conservation Service curve numbers and runoff volume

A simplified and generally accepted method for determining rainfall excess was developed by the United States Department of Agriculture's Soil Conservation Service (SCS). The relationship between accumulated rainfall and accumulated runoff was derived from experimental data for numerous soils, vegetative cover, and land treatment measures.

The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = accumulated direct runoff (inches)
P = accumulated rainfall (inches)
I_a = initial abstraction including surface storage, interception, and infiltration prior to runoff (inches)
S = potential maximum retention (inches)

This equation is particularly easy to use with cumulative rainfall distributions. For purposes of developing project-specific runoff generation relationships, the South Florida Water Management District staff applies this formula using a weighted soil moisture storage value for the maximum retention parameter, S. For example, if a project had the ability to store 6.0 inches of rainfall in the soil profile and it was 50% impervious, then for purposes of calculating the cumulative runoff volumes, use an S value of:

$$S = 6.0 \text{ inches} \times (1 - 0.50) = 3.0 \text{ inches}$$

The relationship between I_a and S was developed from experimental watershed data. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2S$$

Substituting 0.2S for I_a in the runoff equation above yields:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

S values are transformed into curve numbers (CN) by the following equation:

$$CN = \frac{1000}{S + 10}$$

To show the rainfall-runoff relationship graphically see **Figure 5**. From this graph, the predicted runoff can be ascertained.

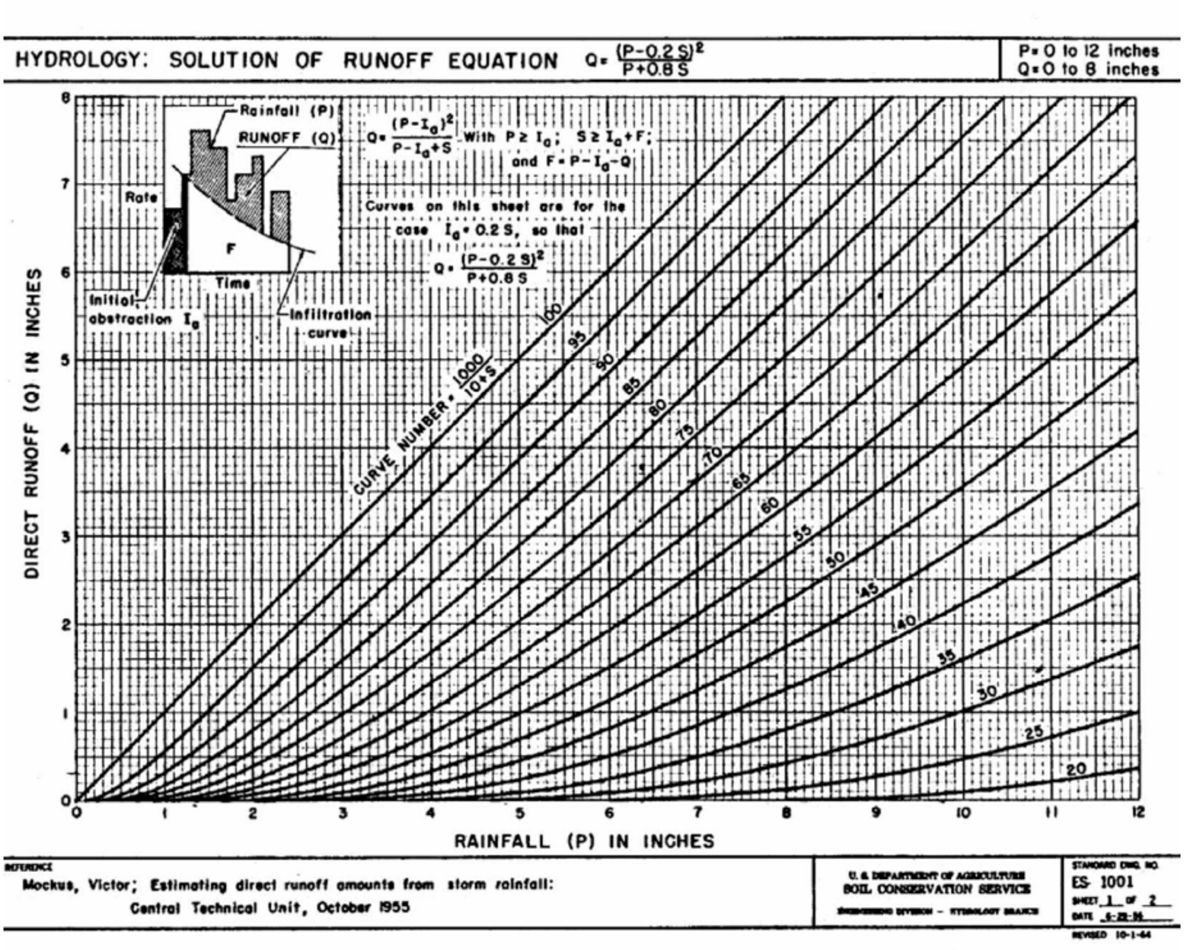


Figure 5. Curve Number Graph for SCS Method

The SCS computational procedure computes peak discharge (q_p), in cubic feet per second, from daily runoff (Q) by means of an equation that uses a peak attenuation factor (K) that has a standard value of 484 in most parts of the United States. The peak factor relates the rising limb to the recession limb of the SCS triangular unit hydrograph.

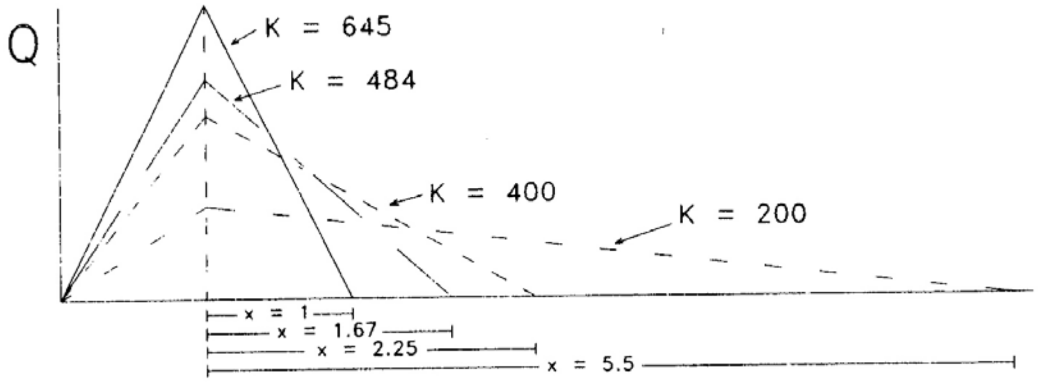


Figure 6. Triangular Unit Hydrograph for SCS Method
with Peak Attenuation Factors

In the South Florida Water Management District, for slopes less than about 5 feet per mile, a value for K of 100 is recommended and for slopes greater than 5 feet per mile a factor of 256 is recommended.

Many computer programs exist that can assist the practitioner with stormwater calculations. Typically the permitting authorities can provide guidance on acceptable programs to use for a given type of project.

C. *Water Quality Aspects*

i. Nonpoint source pollution (NPS)

Much of stormwater pollution occurs from what is known as *nonpoint source* pollution. The term nonpoint source pollution refers to the fact that much of the contaminated waters entering water management and drainage systems result from rainfall runoff events from large areas of land that are often improved with industrial, residential, or agricultural uses. *Point source* pollution to surface waters was historically produced by wastewater treatment plants, industrial facilities, and other identifiable discharge points. Now most of these point sources are permitted and required to meet appropriate water quality standards prior to discharge. Most point sources are not influenced by storm events, but most nonpoint pollution sources are. Nonpoint sources also include atmospheric deposition, groundwater that is contaminated, sediments, and other diverse pollution sources that are not readily pinpointed. As a result, NPS pollution has been identified as a leading cause of surface water pollution, and one of the most difficult environmental problems to adequately resolve.

ii. Sources of pollutants in urban runoff

Common pollutants found in stormwater runoff come from the following major sources:

- **Construction Activities:** Although relatively short-term, soil erosion from exposed land during construction activities is a major source of suspended solids in stormwater runoff. While most of the pollution consists of turbidity from earthwork operations, hydrocarbons from extensive use of large machinery and vehicles are also a major concern. Due to the proliferation of construction activities at any given time, the implementation of short-term pollution prevention measures and BMPs is critical.
- **Agricultural Activities:** These operations, which include farming and nursery activities, as well as equestrian communities, are a major source of pollutants in the form of fertilizer, animal waste, and soil erosion from exposed areas.
- **Street Pavement:** As roads degrade, surface components become common constituents of urban runoff. The largest is the aggregate material itself. Also, smaller quantities of contaminants originate from the asphalt binder, fillers, and substances applied to the surface by daily traffic.
- **Motor Vehicles:** Vehicle use creates pollutants such as fuel, lubricants, tire particles, brake linings, dust, exhaust emissions, asbestos, and heavy metals that collect on roads and in parking lots. Other constituents, such as organics, nutrients, and suspended solids, can adhere to vehicle surfaces and then be washed onto roads by rain and splashing.

iii. Constituents of pollutants in urban stormwater runoff

- **Atmospheric Deposition:** Atmospheric contaminants such as dust and particles from industrial processes, and dust emissions from planes, cars, and exposed land fall on the ground and become mobile in runoff during a storm event.
- **Vegetation:** Organic matter such as leaves, grass, and other plant materials fall or are placed in areas where they can be carried away by stormwater runoff. They can become a large contributor of organic and nutrient pollutants.
- **Land Surface:** Types of land cover and the amounts of vehicular and pedestrian traffic in a particular area have a direct impact on the volumes and types of runoff generated.
- **Litter:** Various kinds of litter, such as food containers, packaging materials, and landscape vegetation, can float in runoff and prevent structural controls from operating properly. In addition, animal droppings have been shown to be a contributor of nutrient and bacterial contamination.
- **Chemicals:** Chemicals such as fertilizers, insecticides, and herbicides used on agricultural fields, roadside areas, and yards, contaminate surface and ground waters.
- **Wastewater:** Contamination from wastewater may occur if septic tanks or sanitary sewer systems overflow during local flooding. Improper

connections between sanitary sewers and stormwater drainage systems may result in discharge of laundry or sanitary waste to drainage canals.

iv. Types of pollutants in urban runoff

This section describes common pollutants found in urban stormwater runoff. Each pollutant has a specific adverse impact on the health of our waterways and environment. A summary of pollutants, sources, and their impacts is provided at the end of this section in **Table 1**.

Sediments

Sediments are solid materials originating mostly from disintegrating rock, eroding soil, and/or accumulated organic material deposited on the land surface. Suspended sediments contribute the largest mass of pollutants to surface waters and cause both short-term and long-term impacts. Sediments clog waterways, smother bottom-living aquatic organisms, and increase turbidity. These conditions are monitored by measuring total suspended solids and turbidity.

Nutrients

Nitrogen and phosphorus are the principal nutrients of concern in urban stormwater. In excess, they increase primary biological productivity and may cause unwanted and uncontrolled growth of algae and undesirable aquatic weeds. Surface algal scum, water discoloration, and the release of toxins from sediment may also occur. The major sources of nutrients in stormwater are urban landscape runoff (fertilizers, detergents, and plant debris), atmospheric deposition, and improperly functioning septic tanks.

Heavy Metals

Heavy metals originate from the operation of motor vehicles, direct fallout, industry, and degradation of highway materials. The most abundant heavy metals typically found in urban runoff are lead, cadmium, chromium, copper, mercury, and zinc. Lead, zinc, and copper account for much of dissolved heavy metals. Except for copper and cadmium, the majority of metals are present in particulate form. These substances can disrupt the reproduction of fish and shellfish. In addition, heavy metals accumulate in fish tissue, posing a threat to humans. Another human and environmental threat is the potential for ground water contamination.

Oxygen-Demanding Substances

Numerous organic materials are decomposed by microorganisms, thereby creating a need for oxygen. Oxygen consumption during this process results in an oxygen deficit that can kill fish and other aquatic life forms. Data have shown that urban runoff with high concentrations of decaying organic matter can severely depress dissolved oxygen levels after storm events. Proper levels of dissolved oxygen are critical to maintaining water quality and aquatic life. Oxygen-demanding substances found in urban stormwater can be measured through biochemical oxygen demand, chemical oxygen demand, and total organic carbon.

Petroleum Hydrocarbons

Petroleum hydrocarbons are derived from oil products. They include oil and grease, the compounds benzene, toluene, ethyl benzene, and xylene, and a variety of polynuclear aromatic hydrocarbons. Some petroleum hydrocarbons are known to be toxic to aquatic life at low concentrations. Hydrocarbons have a high affinity for sediment, and they collect in bottom sediments where they may persist for long periods of time and result in adverse impacts on benthic communities. The source of most such pollutants found in urban runoff is parking lots and roadways, leaking storage tanks, vehicle emissions, and improper disposal of waste oil.

Pathogens

Urban runoff typically contains elevated levels of pathogenic organisms such as coliform bacteria and viruses. Pathogens contaminate surface and ground water preventing swimming in water bodies, drinking from certain water sources, and harvesting of fish. This problem may be especially prevalent in areas with porous or sandy soils. Pathogens in urban runoff typically emanate from wastes (including pets and birds), failing septic systems, illicit sewage connections, and boats and marinas.

Toxics

Many different toxic compounds (priority pollutants) have been found in urban runoff. Toxic synthetic organic compounds include a variety of manufactured compounds such as pesticides, solvents, and various household and industrial chemicals.

In sufficiently high concentrations, detergents and similar synthetic organic surfactants can interfere with the respiration of fish and other aquatic animals. The presence of detergents indicates there are either improper discharges into the stormwater collection system or that wastewater is entering through overflowing sanitary sewers or septic tanks. Detergents also indicate that loads of nutrients in stormwater may be significant as water conditioning chemicals are generally phosphate-based.

Others

Impacts not related to specific pollutants can also occur. These impacts can be caused by changes in the temperature or physical properties of the water. Changes in water temperature affect some important physical properties and characteristics of water, such as specific conductivity and conductance, salinity, and the solubility of dissolved gases.

Water holds less oxygen as it becomes warmer resulting in less oxygen available for respiration by aquatic organisms. Higher temperatures also increase the metabolism, respiration, and oxygen demand of fish and other aquatic life. Water temperature changes can result from increased flows, the removal of vegetative cover, and increased amounts of impervious surfaces. Alkalinity, dissolved oxygen, pH, hardness, and conductivity can also affect the behavior of materials in water. Metals generally become more soluble as pH drops below neutral and hence become more available to harm organisms (bioavailable). Depleted dissolved oxygen can also make some metals more soluble.

Table 1. Pollutants in Stormwater Runoff

Pollutant	Source	Impact to Water Body
Sediments	Eroding rock, soil, or organic material from building sites, streets, and lawns	Clogged waterways, increased turbidity, and reduction of bottom living organisms
Nutrients	Nitrogen and phosphorous from landscape runoff, atmospheric deposition, and faulty septic tanks	Unwanted growth of algae and undesirable aquatic weeds, scum, and water discoloration
Heavy Metals	Lead, cadmium, chromium, copper, mercury, and zinc from vehicles, highway materials, atmospheric deposition, and industry	Disruption of fish reproduction, fish toxicity, and potential for ground water contamination
Oxygen Demanding Substances	Decaying organic matter	Death of fish and aquatic life forms
Petroleum Hydrocarbons	Oil, grease, and various hydrocarbons from roads, parking lots, leaking storage tanks, and improper oil disposal	Toxicity to aquatic life and adverse impacts on benthic communities
Pathogens	Coliform bacteria and viruses from animal waste, septic systems, sewer cross-connections, and boats and marinas	Contamination of swimming, fishing areas, or drinking water
Toxics	Pesticides, solvents, and chemicals from lawns, gardens, and commercial and household activities	Interference with respiration of fish and aquatic life forms
Others	Changes in the temperature or physical properties of water	Increased oxygen demand by fish and aquatic life forms and increased availability of toxic elements that harm organisms

v. Methods of quantifying pollutants in urban stormwater runoff

Water pollutants can be quantified in terms of concentration or load. Concentration provides a method for comparing different storm events and relating one site with another. Loads are used to make relative comparisons of the same site and predict potential impacts and pollutant attenuation capabilities of various stormwater management practices.

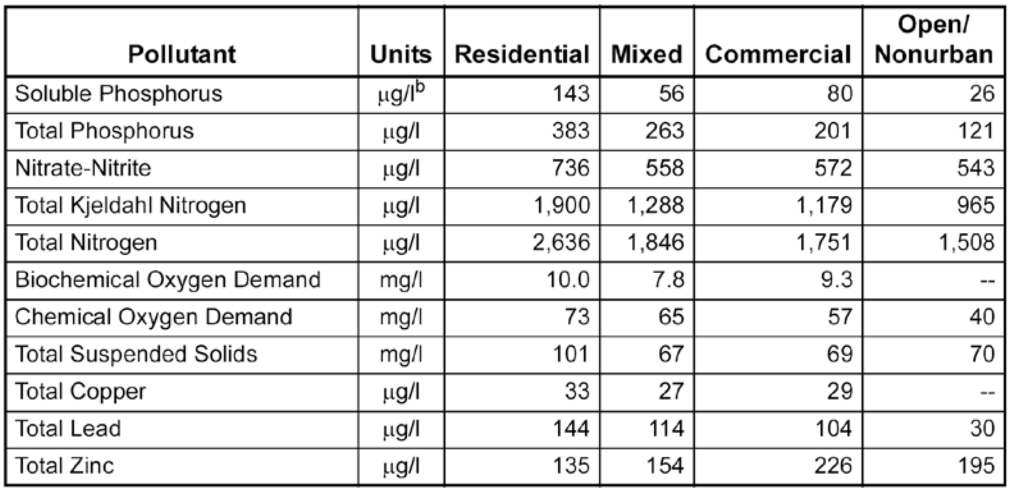
Concentration

Concentration is the mass of pollutant per unit volume of water sample taken at a particular point in time. It is a static test to measure pollutant content. The amount of pollutant transported by runoff has been shown to vary considerably during each storm event as well as from site to site. Pollutant concentrations for a given site may vary due to variability of rainfall intensity, frequency of the rain events, soil types, land uses, weather patterns, and intensity of watershed activities. Concentrations are usually expressed as milligrams per liter (mg/l).

Because of the difficulty in characterizing pollutant concentrations during dynamic flow conditions, the accepted practice is to determine an event mean concentration. This value is found by analyzing a single sample composited from a series of samples taken at different points in time throughout the runoff event and combined in proportion to the flow rate at the time of sampling, or by calculating the total pollutant mass discharged divided by the total discharge volume. Event mean concentration is generally accepted as the primary estimation of a characteristic pollutant concentration for individual storm events. This provides a method for comparing different storm events and relating one site with another. A good deal of research has been conducted showing the link between land use and water quality. **Table 2** shows national data for median event mean concentrations by land use category.

The interrelationships of rainfall runoff and soil erosion processes are dynamic and complex. Through research and a sound understanding of hydrologic processes, simple assumptions can be made to produce reasonable and practical runoff and soil erosion estimates. **Figure 7** shows typical pollutant concentrations in stormwater runoff throughout a storm event. Most pollutants are flushed at the beginning of a storm event. Runoff then accumulates slowly and peaks over time.

Table 2. Median Event Mean Concentrations by Land Use Category[a]



Pollutant	Units	Residential	Mixed	Commercial	Open/ Nonurban
Soluble Phosphorus	µg/l[b]	143	56	80	26
Total Phosphorus	µg/l	383	263	201	121
Nitrate-Nitrite	µg/l	736	558	572	543
Total Kjeldahl Nitrogen	µg/l	1,900	1,288	1,179	965
Total Nitrogen	µg/l	2,636	1,846	1,751	1,508
Biochemical Oxygen Demand	mg/l	10.0	7.8	9.3	--
Chemical Oxygen Demand	mg/l	73	65	57	40
Total Suspended Solids	mg/l	101	67	69	70
Total Copper	µg/l	33	27	29	--
Total Lead	µg/l	144	114	104	30
Total Zinc	µg/l	135	154	226	195

a. Source: USEPA, 1983

b. µg/l - micrograms per liter

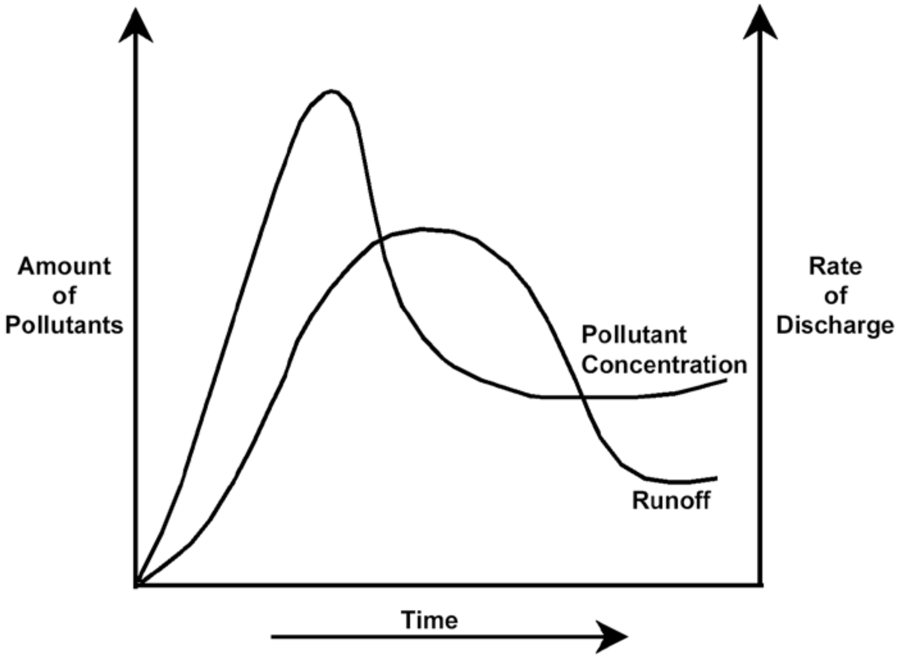


Figure 7. Pollutant Concentration during a Storm Event

Load

Load is the mass of pollutant delivered to a receiving water body during a period of time. It associates concentrations of a pollutant to a volume of runoff at a given specific flow duration. Loads are usually expressed on an annual basis as kilograms per year, and are used to make relative comparisons of the same site.

Evaluating pollutant loads on a mass basis provides further insight of potential impacts than might be obtained from evaluating concentration data only. Knowledge of mass loading rates also provides an understanding of pollutant attenuation capabilities of various stormwater management practices. Estimating cumulative (usually annual) pollutant loads for a watershed can be achieved by using the following types of data:

- Published yield values
- Simple empirical models
- Published regression equations
- Computations from site-specific or modeled flow data and either local or published concentrations
- Computer generated, mechanistic models

Many studies have documented a general order of loading from urban land uses. This order, from highest to lowest, is as follows: industrial and commercial, freeway, higher density residential, lower density residential and open land. However, construction phases can produce far higher loads of solids and pollutants in soil, like phosphorous, than in any finished land use.

IV. STORMWATER BEST MANAGEMENT PRACTICES

A stormwater BMP is a method or combination of methods found to be the most effective and feasible means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals. Problem assessment, including technological, economic, and institutional considerations; examination of alternative practices; and appropriate public participation, are all considered before implementing BMP solutions. The following three principles apply in the improvement of water quality through BMPs:

- Prevention…...Avoiding the generation of pollutants
- Reduction……Reducing or redirecting pollutants
- Treatment……Capturing and treating pollutants

Methods for controlling pollutants in stormwater runoff can be categorized as nonstructural or structural practices. The two methods are often used together to control runoff in new developments, existing developments, and construction sites.

A. *Nonstructural BMPs*

Nonstructural BMPs are practices that improve water quality by reducing the accumulation and generation of potential pollutants at or near their source. They do not require construction of a facility, but instead provide for the development of pollution control programs that include prevention, education, and regulation. These can be classified as follows:

- Planning and regulatory tools
- Conservation, recycling, and source controls
- Maintenance and operational procedures
- Educational and outreach programs

Most nonstructural BMP options are applicable for use in residential, commercial, industrial, agricultural, and nursery operations in newly developed or existing watersheds. They can be used to complement structural BMPs in developing areas, but may be the only option in existing developments. These options are based on changes in human practices that result in the ***prevention or reduction*** of the generation of contaminants into stormwater runoff. Because they rely on actions and not structures, they must be implemented consistently and repetitively over time. Any process for selecting nonstructural BMPs should take into consideration the incorporation of the following elements: planning and regulatory tools; conservation, recycling, and source controls; maintenance and operational procedures; and educational and outreach programs.

Planning and Regulatory Tools

Action plans and regulations encourage or mandate management practices that prevent, reduce, or treat stormwater runoff. For example, setbacks can be required from waterways, minimum allowable impervious areas within a site can be established, and criteria for treating runoff can be mandated. Plans for stormwater runoff control should be submitted to the appropriate agencies for review and approval. The planning process gives the public an opportunity to participate in the decision-making process regarding stormwater quality for existing and future land uses within their area. Existing federal, state, local, and site-specific requirements provide the basis for building regulatory programs.

Ordinances and Regulatory Programs

Federal agencies are tasked with establishing nationwide programs to address stormwater pollution. The state of Florida has generally established regulations by adopting the appropriate Code of Federal Regulations title into the Florida Statutes and the Florida Administrative Code. Water management districts function under these codes and require permits for the construction and operation of water management systems, water usage, or water quality monitoring plans.

Local governments play an important role in establishing regulatory programs that provide opportunities to meet specific local objectives. Regulatory measures must comply with state and federal mandates and should address such issues as hazardous materials codes, zoning, land development and land use regulations, water shortage and conservation policies, and controls on types of flow allowed to drain into sanitary municipal storm sewer systems. For a successful local program the following elements should be considered:

- Community/business composition
- Land use patterns
- Local practices
- Community concerns
- Institutional characteristics

Ordinances are laws or rules issued by a local government under legal authority granted by statutes. They can include findings of fact, objectives or purposes, definitions, permitting requirements, variances, performance/design standards, and enforcement policies. For further information and samples of ordinances, refer to Chapter 8 of the Florida Department of Environmental Protection's *Florida Development Manual - A Guide to Sound Land and Water Management*.

Low-Impact Development

In low-impact development, stormwater is managed in small, cost-effective landscape features located on each land parcel rather than being conveyed to large, costly, pond facilities located at the bottom of drainage areas. The concept of source control is quite different from end of pipe treatment. Hydrologic functions such as filtration, frequency, and volume of discharges, and ground water recharge can be maintained by reducing impervious surfaces, functional grading, open channel sections, reuse of runoff, and using multifunctional landscape features such as rain gardens, swales, mulch, and conservation areas.

Conservation, Recycling, and Source Controls

Conservation Plan

All water users, including domestic, utility, commercial, agricultural, and recreational, have an opportunity and responsibility to conserve water to reduce or eliminate the amount of water potentially requiring stormwater runoff treatment.

Promotion of conservation practices is essential in all communities. A good water conservation plan should include a framework for the following components:

- Appropriate lawn irrigation
- Adoption of Xeriscape® landscape ordinances
- Installation of ultra-low volume plumbing fixtures in new construction
- Adoption of conservation-oriented rate structures by utilities
- Implementation of leak detection programs by utilities with unaccounted for water loss
- Institution of public education programs for water conservation

Using Irrigation-Quality Water and Conserving Stormwater

Stormwater can be used as a source for irrigation water. It may involve treating and disinfecting but usually does not. Capturing stormwater in ponds and cisterns allows this water to be saved for future use. Both of these storage areas can provide the following benefits:

- Landscape irrigation for parks, golf courses, highway medians, and residential lawns
- Agricultural irrigation for crops, pasture lands, and nursery operations
- Ground water recharging either directly or through rapid infiltration basins
- Industrial cooling or in-manufacturing processes
- Creating or restoring wetlands
- Fire protection
- Separate toilet piping systems in industrial or commercial buildings
- Aesthetic enhancements for ponds, fountains, and landscape features
- Dust control for construction sites or unpaved road communities

Source Control Measures

These measures address disposal practices of contaminants on the typical urban landscape. They may reduce or eliminate pollutants deposited on land surfaces that may eventually come in contact with stormwater and be transported to receiving waters. Water quality benefits may be derived from addressing the following:

- Erosion and sediment control during construction
- Collection and proper disposal of animal waste
- Collection and proper disposal of solid waste
- Proper disposal and composting of yard waste
- Proper disposal and recycling of unused toxic waste materials
- Proper storage, disposal, and recycling of unused automotive fluids and prevention of fluid leaks
- Modified use of chemicals such as fertilizer, pesticides, and herbicides
- Safe storage, handling, and disposal of hazardous household products
- Green Roofs and cisterns can be used to cool buildings, conserve water from roof runoff, and provide peak flow reductions.

Maintenance and Operational Procedures

Nonstructural maintenance and operational procedures can be used to prevent or reduce the need for more costly structural treatment controls. To ensure the proper operation of stormwater BMP systems, periodic maintenance tasks are required. The efficiency of an entire system relies on the proper upkeep of all BMP components.

Nonstructural maintenance operations may consist of turf and landscape management, street cleaning, catch basin cleaning, road maintenance, canal/ditch maintenance, and modification of structural operations.

Turf and Landscape Management

Lawns and grasses planted for aesthetic and recreational use, surface stabilization, and erosion control require routine maintenance that includes irrigation, mowing, fertilization, targeted pest management, aeration, and/or detaching. Mowing should be performed at optimal times, such as when no significant rainfall events are predicted.

Municipal “no dumping” ordinances should be enacted to prevent the disposal of cuttings and clippings in or near drainage facilities. Composting is a good disposal alternative, and the installation of a yard waste composting facility is a viable management tool. Turf and landscape management procedures should be consistent with vegetation use, growing season, and the amount of rainfall.

Street Cleaning

Routine street cleaning removes accumulated depositions of solids that may otherwise be transported as contaminants in the first flush of stormwater. Efficiency depends on sweeping frequency which appears to be more effective in areas with distinct wet and dry seasons. Sweeping should increase just before the rainy season. Mechanical broom sweepers, vacuum sweepers, and street flushers are typically used for cleaning and are very effective in removing larger particles (>50 microns) and associated pollutants (i.e., solids and heavy metals). Parked cars can be an obstacle to effective sweeping and parking regulations may be required. Costs for purchasing equipment and implementing a program can be significant.

Catch Basin Cleaning

Accumulated sediments should be removed from catch basins on a regular basis to prevent clogging. Basins should be cleaned before the sump is 40 percent full. Maintenance schedules should be targeted to those areas with the highest pollutant loading. Capital costs may be high, as communities with numerous basins will need to procure mechanical cleaners such as vacuum trucks.

Road Maintenance

Deteriorating roadway surfaces can contribute to contamination of stormwater. Potholes and worn pavement should be promptly repaired to reduce sediment loading. Minimizing the size of the impervious area is the most effective method to reduce stormwater pollution from the roadway. Aggressive maintenance programs are more cost effective than complete roadway replacements.

Canal/Ditch Maintenance

Ditches that carry heavy flow concentrations should be periodically checked for collapsed or blocked flowways or degradation of flowway lining materials. The channel bottom should be dredged if a buildup of sediment occurs. Illegally dumped items should be removed to reduce possible pollutants and achieve aesthetic enhancement. “No littering” signs can be posted with a call-in number to report dumping in progress. Also, if water quality will not be compromised, the characteristics of the channel can be modified to improve hydraulics.

Modification of Structural Operations

Schedules for structural operations can be modified to optimize water quality objectives. Activities such as diverting low-quality water away from critical habitat areas, increasing the detention times or reducing the discharge orifice size in existing ponds, storing water for future use during drought periods, recharging the ground water table, and mixing clean water with degraded water to enhance quality are all examples of modifying operations to achieve priorities. Successful operations will reduce risk, increase water supply reliability, and enhance water quality.

Educational and Outreach Programs

Public education is a BMP that can be implemented to meet the individual needs and interests of each segment of the community. Outreach programs should be integrated into a community's overall plan for stormwater management to educate employees, the public, and businesses about the importance of protecting stormwater from improperly used, stored, and disposed pollutants. Often people are not aware of the cumulative effects of pollution-generating activities. Once a pollutant has been linked with a particular community, support for a volunteer effort and public education campaign can be gained through the local civic association.

Public and private funding partnerships may be needed to ensure participation and encourage development of information and infrastructure improvements. Public information can be expensive to develop and distribute and must be periodically updated and redistributed. A specific course of action must be defined and the associated cost to implement a solution determined for each problem. The initiation of a well-coordinated, comprehensive campaign will be more effective at reaching audiences than a series of separate actions that seem unrelated.

Potential funding sources for education programs might include agencies such as the local public works department, health department, park authority, forestry division, state department of natural resources, United States Department of Agriculture, and private conservation groups.

The public should be educated about the relationship they have with the watershed in the area where they live. Programs informing citizens of practices that reduce sources of potential pollutants in runoff will encourage them to become part of the solution. The effectiveness of a program can be assessed by estimating how many people will hear the message, change their behavior, and to what degree their behavior changes. A public education plan should consist of several kinds of activities, such as:

- Public surveys to assess use of toxic materials, disposal practices, and overall environmental awareness
- Frequent and consistent campaign messages using a mission statement, logo, and tag line
- Campaign products such as door hangers, pamphlets, guidebooks, signs, press releases, or classroom/library displays
- Public outreach activities such as having a field day where a local water quality expert comes to a community to demonstrate ways of reducing pollution
- Neighborhood programs, such as the following:
    - Identifying storm drains with stenciling to discourage dumping
    - Distributing toxics checklist for meeting household hazardous waste regulations
    - Producing displays and exhibits for school programs
    - Distributing free seedlings for erosion control
    - Creating volunteer opportunities such as water quality monitoring
    - Conducting awards ceremonies for specific neighborhood projects

B. *Structural BMPs*

Structural BMPs involve building an engineered “facility” for controlling quantity and quality of urban runoff. These structures treat runoff at either the point of generation or the point of discharge to either the storm sewer system or receiving waters. Most require some level of routine maintenance. Structural BMPs can be categorized as retention systems, detention systems, or other systems.

Structural BMP mechanisms for controlling stormwater runoff in developing areas fall into three main categories:

1) Retention systems
2) Detention systems
3) Other Systems

Prior to the installation of structural BMPs, institutional ordinances and regulatory programs must be in place. These will provide for the fiscal resources to review and approve BMP plans, inspect their operation, and enforce violations in management practices. Ordinances will also assure that temporary erosion and sediment controls are in place during the construction phase.

Retention Systems

Retention systems rely on absorption of runoff to treat urban runoff discharges. Water is percolated through soils, where filtration and biological action remove pollutants. Systems that rely on soil absorption require a deep layer of permeable soils at separation distances of at least 1 foot between the bottom of the structure and seasonal ground water levels. Using retention systems in a watershed will help to preserve or restore predevelopment hydrology, increase dry weather base flow, and reduce flooding frequency. Retention BMP systems include exfiltration trenches, concrete grid pavers, pervious pavement, vegetated filter strips, grassed swales, and swale blocks.

Where ground water requires protection, retention systems may not be appropriate. Restrictions may also apply to systems located above sole source (drinking water) aquifers. Where such designs are selected, they should be incorporated with the recognition that periodic maintenance is necessary for these areas. Long-term effectiveness in most cases will depend on proper operation and maintenance of the entire system. Site and maintenance considerations for retention BMP systems are summarized at the end of this section in **Table 3**.

Retention Basins

Retention basins are depressed areas where incoming urban runoff is temporarily stored until it gradually filtrates into the surrounding soil. These should gradually drain down to maintain aerobic conditions that favor bacteria that aid in pollutant removal and to ensure the basin is ready to receive the next storm. Runoff entering the basin is sometimes pretreated to remove coarse sediment that may clog the surface soil pore on the basin floor. Concentrated runoff should flow through a sediment trap, or a vegetated filter strip may be used for sheetflow. For water quality, retention is better than detention as the pollutants are not resuspended and flushed out with subsequent rainfall events as might occur with detention.

Exfiltration Trenches

Exfiltration trenches are perforated pipes buried in trenches that have been backfilled with stone or sand/aggregate. Urban runoff diverted into the pipe gradually infiltrates from the pipe into the trench and into the subsoil, eventually reaching the ground water. A filter cloth surrounding the rock trench is used to minimize clogging.

Concrete Grid Pavers and Porous Concrete

Surfaces such as pervious concrete and concrete grid pavers interspersed with areas of gravel, sand, or grass can reduce runoff volumes and trap vehicle-generated pollutants. Pavers are most effective in very low traffic grassed areas with relatively pervious in-situ soils (nondepressional soils) and require moderate maintenance. Pervious concrete is able to handle more load and traffic, like in a parking lot. For best results, these options should be combined with other BMPs.

Vegetated Filter Strips

Strips of land with vegetated cover are designed to reduce sediment and remove pollutants. They are designed to receive overland sheetflow, but provide little treatment for concentrated flows. Recommended areas of use are for agriculture and low density development. Vegetated filter strips are often used as pretreatment for other structural practices, such as retention ponds and exfiltration trenches.

Grassed filter strips may develop a berm of sediment at the upper edge that must be periodically removed. Mowing will maintain a thicker vegetative cover, providing better sediment retention.

Forested strips next to water bodies should be left undisturbed except for the removal of trees that present unusual hazards and small debris that may be refloated by high water. Periodic harvesting of some trees not directly adjacent to water bodies removes sequestered nutrients and helps maintain an efficient filter through vigorous vegetation.

Grassed Swales and Swale Blocks

Grassed swales are filtration and conveyance mechanisms that are generally used to provide pretreatment before runoff is discharged to treatment systems. Swales are typically shallow, vegetated, man-made trenches with a width-to-depth ratio equal to or greater than 6 to 1, or side slopes equal to or greater than 3-feet horizontal to 1-foot vertical. The established width should be maintained to ensure the continued effectiveness and capacity of the system. Grassed swales should be mowed to stimulate vegetative growth, control weeds, and maintain the capacity of the system. Swale blocks serve to provide a barrier to slow stormwater flows, thereby inhibiting resuspension of sediments, allowing greater settling of sediments, and allowing for more infiltration of stormwater into the ground water.

Detention Systems

Detention BMP systems include dry and wet detention ponds and constructed wetlands. Site and maintenance considerations for detention BMP systems are summarized at the end of this section in **Table 4**.

Dry Detention Ponds

Dry detention ponds detain a portion of urban runoff for a short period of time (i.e., up to 24 hours after a storm) using fixed openings to regulate outflow at a specified rate and allowing solids and associated pollutants time to settle out. In general, these systems are effective for attenuating the hydrograph.

However, dry detention ponds are not as effective in pollution removal as retention ponds. They are not very effective in removing soluble pollutants from stormwater, and they have low treatment efficiency for nutrients. Also, many pollutants that settle out can be resuspended in subsequent storm flows and discharged from the basin. Many dry basins end up with permanent pools of water because runoff from previous storms has not flowed out or infiltrated before another storm occurs. Their value is mainly for attenuating peak flows, not for water quality improvement.

Usual location requirements call for a minimum of one foot from control elevation to the bottom of the detention zone. Therefore, constructing dry detention ponds on wetlands and floodplains should be avoided. Where drainage areas are greater than 250 acres and ponds are being considered, inundation of upstream channels may be of concern.

Wet Detention Ponds

Wet detention ponds are designed to maintain a permanent pool of water and temporarily store urban runoff until it is released at a controlled rate. Hydraulic holding times are relatively short, such as hours or days. These systems are more efficient in removing soluble pollutants (nutrients) than dry detention due to the biological activity in the vegetation and water column. Enhanced designs include a forebay to trap incoming sediment where it can be easily removed. A littoral zone can also be established around the perimeter of the pond.

Constructed Wetlands

Constructed wetlands and multiple pond systems treat runoff through adsorption, plant uptake, filtration, volatilization, precipitation, and microbial decomposition. Multiple pond systems in particular have shown potential to provide much higher levels of treatment. Constructed wetlands are designed to simulate the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollutants and decrease loadings. Many of these systems are currently being designed to include vegetated buffers and deep water areas to provide wildlife habitat and aesthetic enhancements. Periodic maintenance is required for these systems. Long-term effectiveness will generally depend on proper operation and maintenance of the entire system.

Constructed wetlands differ from artificial wetlands created to comply with mitigation requirements in that they do not replicate all of the ecological functions of natural wetlands. Enhanced designs may include a forebay, complex micro topography, and pondscaping with multiple species of wetland trees, shrubs, and plants.

C. *Other Systems*

Systems other than retention and detention systems include reuse ponds, water quality inlets, separation devices, and chemical treatment. Site and maintenance considerations for other BMP systems are summarized at the end of the section in **Table 5**.

Reuse (Irrigation) Ponds

Reuse or irrigation ponds are used to reduce both the volume of stormwater discharge and the pollutant mass. Thus, their value is in areas where a hydrologic balance or a total maximum daily load must be maintained. Their area and volume are based on reuse curves (REV curves) that are published by the DOT, DEP, or the SJRWMD. The area of the pond is typically no larger than the area of retention when in a watershed of critical concern such as an outstanding Florida water body or recharge area. The pollutant mass removal efficiency can be as high as 95% by reducing both the water volume and the concentration of stormwater ultimately discharged.

Since the stormwater replaces in many instances potable water, there is a recognized savings in potable water. In addition, utilities have been created that result in a return on investment to the operator of the ponds.

Water Quality Inlets and Filters

Water quality inlets rely on settling to remove pollutants before discharging water to the storm sewer or other collection system. They are also designed to trap floating trash and debris. When inlets are coupled with oil/grit separators and/or hydrocarbon absorbents, hydrocarbon loadings from high traffic/parking areas may be reduced.

However, experience has shown that pollutant-removal effectiveness is limited, and the devices should be used only when coupled with extensive clean-out methods. Maintenance must include proper disposal of trapped coarse-grained sediments and hydrocarbons. Clean-out and disposal costs may be significant.

Catch basins are water quality inlets in their simplest form. They are single-chambered inlets with a lowered bottom to provide 2 to 4 feet of additional space between the outlet pipes for collection of sediment at the bottom of the structure.

Some water quality inlets include two chambers. The first provides effective removal of coarse particles and helps prevent premature clogging of the filter media. A second chamber contains a sand filter to provide additional removal of finer suspended solids by filtration.

Separation Devices

Separation devices include sumps, baffle boxes, oil/grit separators, and sediment basins to capture trash, sediments, and floating debris. They are efficient within specific ranges of volume and discharge rates. Control units usually have a forebay to pretreat discharges by separating heavy grit and floating debris before it enters the separator. Separation processes use gravity, vortex flow, centrifugal force, and even direct filtration. Further treatment may be accomplished by adding chemicals. After separation, the sediment is collected and transported or pumped. These devices may have a high initial cost.

Chemical Treatment

Chemical processes include coagulation coupled with solids separation to remove pollutants. Iron, aluminum metal salts, and alum are used to coagulate compounds. Also, polymers can be added for flocculation and to induce settling. The resulting settled floc and solids would need to be disposed and may need dewatering prior to disposal.

Chemical processes offer the advantage of low land requirements, flexibility, reliability, decreased detention time requirements, and the ability to enhance water quality to levels substantially lower than could be achieved using other methods alone. The drawbacks are high capital, operations, and maintenance costs, and solid waste management requirements.

D. *Combination Treatment Train Approach*

Although the basic principles of managing stormwater remain the same, they should be uniquely adapted to the special requirements of each project. It should be understood that no one BMP can be the “cure all” for a particular project, but if several are used together in a linked fashion like cars in a train (a “BMP treatment train”), adverse effects of urban stormwater runoff can be reduced or alleviated.

A careful assessment of stormwater management conditions should be made before choosing a system of comprehensive BMPs. First, potential pollutant sources and high-risk areas of pollution must be identified. Then, the magnitude of the problem must be evaluated by monitoring and analyzing runoff to determine the amount and type of pollutants in terms of concentration or load. Understanding the source, amount, and characteristics of pollutants in stormwater runoff is essential in applying a screening process for selecting appropriate BMPs.

E. *BMP Selection Criteria and Design*

Selecting appropriate BMPs is an intricate process requiring thorough study and research. Success will ultimately depend on choosing feasible options that specifically address project conditions and objectives. A comprehensive management program should include a combination of structural and nonstructural components that are properly selected, designed, implemented, inspected, and regularly maintained. Whether implementing BMPs to meet regulatory requirements, address water quality issues in a watershed, or attack acute local pollution problems, the project should be evaluated for the following factors through a feasibility screening process:

- Physical and technical limitations
- Pollutant reduction capabilities
- Cost considerations
- Supplemental benefits/side effects
- Public acceptance

Physical and Technical Limitations

Watershed Area. The size of the area generating and/or contributing to stormwater runoff must be considered. Retention, exfiltration, concrete grid pavers, and filter BMPs generally are more suitable for smaller areas. Pond BMPs typically require a larger drainage area to assure proper operation.

Area Required for the BMP Option. Many BMPs are land intensive so adequate area must be available at the site for construction. Underground installations of certain BMPs can be costly maintenance items.

Pollutant Type and Loading. Most BMPs are effective at removing particulate related pollutants. Some BMPs, primarily those with vegetative components, can also reduce dissolved constituents. Many are susceptible to clogging. Pretreatment can increase effectiveness, reduce maintenance, and extend the life of BMPs.

Soil Type. The permeability of soil has a direct influence on effectiveness, especially for retention practices. Soils such as silt and clay can influence the settling capabilities of BMPs.

Slope and Flow Characteristics. Water ponding or flow velocities may cause instability or erosion of sediment, which will eliminate some BMP options.

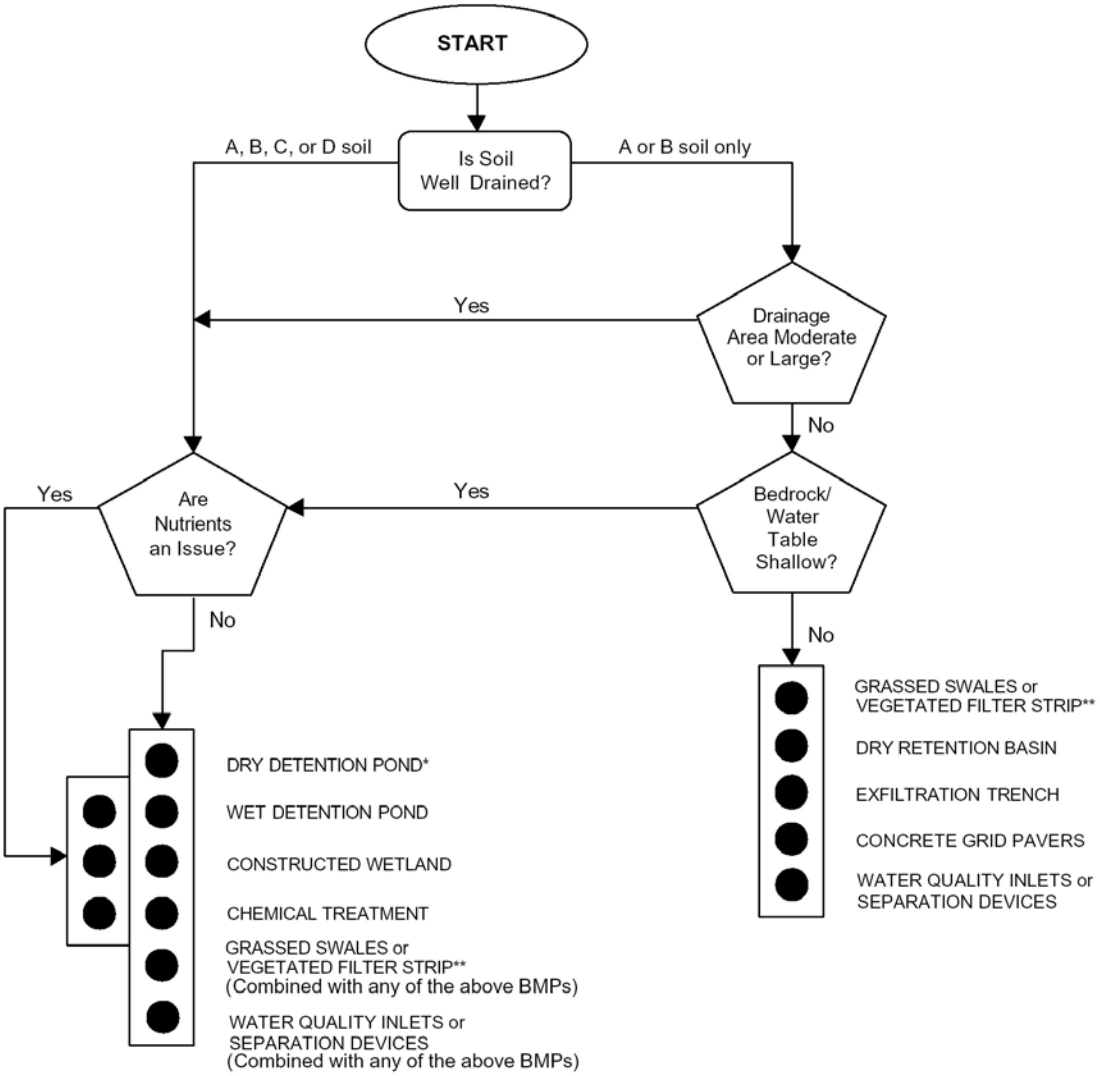
Water Table Elevation. For retention systems, effectiveness and maintenance costs can be related to how close the bottom of the BMP is to the water table.

Bedrock or Hardpan. Restrictive soil layers or rock can impede downward infiltration of runoff or make excavation for ponds impossible or expensive.

Location. BMPs should not be located close to building foundations, septic tanks, or drinking wells. Seepage problems or ground water pollution can result from retention BMPs.

Receiving Waters. Receiving waters such as lagoons and estuaries would generally benefit from reductions in total volumes of runoff. However, normal timing and flow volumes into saline habitats must be considered as an appropriate freshwater/saltwater mix is needed to support these environments.

Figure 8 shows a generalized diagram to assist in determining potential BMP options to remove pollutants under specified site conditions. Special conditions may dictate the selection of alternative BMP options. For example, in an area with a high water table, an extended detention basin may not be feasible because basin excavation would be required.



SOIL TYPES BASED ON SOIL CONSERVATION SERVICE CLASSIFICATION
A: Sand, Loamy Sand
B: Sandy Loam, Loam
C: Silt Loam, Sand, Clay Loam
D: Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay, Clay

* Option may not be feasible if excavation is required in areas with high water tables.
** Options can only be used when slopes along the flow path are moderately low.

Adapted from Camp et al., 1993

Figure 8. BMP Options for Specified Site Conditions

F. *BMP Implementation Opportunities*

New Development

Before development occurs, land in a watershed is available for a number of pollution prevention and treatment options. While BMPs can be implemented during the planning, design, and construction stage, they must continue to be implemented during the life of the project. Prevention practices such as planning and zoning tools to ensure setbacks, buffers, and open space requirements can be implemented with ease at the planning stage of any development with a high degree of success. In addition, compliance with local regulations through permitting processes can guarantee incorporation of treatment options such as wet ponds or constructed wetlands that can improve the water quality of stormwater runoff. All BMPs discussed in this document are applicable for new developments as site conditions allow.

Retrofitting

In already developed areas, pollution prevention and reduction practices may be more feasible than treatment controls due to land restrictions. A comprehensive management plan can be developed to first identify pollutant reduction opportunities, then protect existing natural areas that can help control runoff, and finally begin ecological restoration and retrofit activities to clean up degraded water bodies. Citizens can help prioritize the cleanup strategies, volunteer to become involved with restoration efforts, and help protect ecologically valuable areas.

Installing or retrofitting water management systems in existing developed areas can be a difficult and costly endeavor. Communities can examine areas where BMPs were constructed for flood control purposes to determine if they can be modified to provide water quality benefits. For example, a dry pond can be converted to a wet pond or it can be modified to increase the detention time by reducing the size of the control outlet. Wet ponds can be planted with aquatic vegetation to promote biological uptake processes. When selecting retrofit program control options, be sure to include structural and nonstructural BMPs. Some examples of BMP options are shown in **Table 6**.

Site Construction

During the construction stage, whether for new development or retrofit, BMPs can be implemented to control pollutants resulting from the erosion of disturbed soils. Most of these practices focus on controlling the amount of soil erosion and sedimentation, thereby minimizing subsequent adverse impacts of downstream water bodies. In addition, application, generation, and migration of toxic substances can be limited by properly storing, handling, applying, and disposing of pesticides, petroleum products, nutrients, solid wastes, and construction chemicals. For example, construction sites should establish fuel and vehicle maintenance staging areas; equipment and machinery washing areas; and separate storage, handling, and mixing areas for pesticides and fertilizers, all located away from waterways. As with new development and retrofits, the educational component is critical to the effectiveness of any of the BMPs.

Construction workers need to be trained about the goals of the plan and actions required of them for the BMP to be successful.

An effective plan for minimizing and controlling erosion and sedimentation during construction shall include, at a minimum, the following basic principles:

- Minimize soil exposure through organized scheduling of grading and construction activities
- Retain existing vegetation whenever feasible
- Stabilize all denuded areas within 3 days after final grading; disturbed areas that are inactive and will be exposed to rain for 30 days or more should be temporarily stabilized; stabilization techniques include mulches, vegetation and sod, and chemical applications
- Control runoff by diverting stormwater away from stripped areas or newly seeded slopes, minimize the length and steepness of slopes, and install check dams, level spreaders, and outlet protection to prevent erosion
- Install sediment trapping structures such as silt traps, sediment basins, filter fabric, perimeter dikes, and inlet protection
- Inspect and maintain control measures regularly

G. *Maintenance of Stormwater Management Systems*

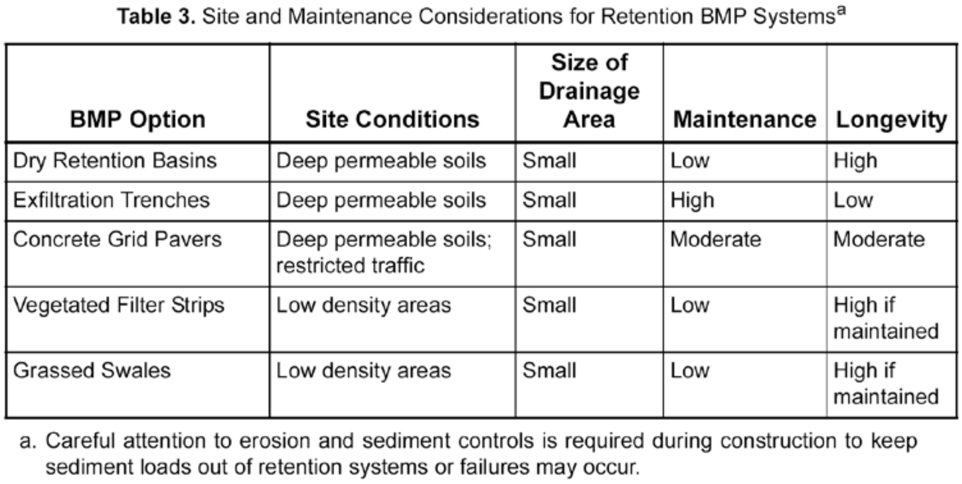


Table 3. Site and Maintenance Considerations for Retention BMP Systems[a]

BMP Option	Site Conditions	Size of Drainage Area	Maintenance	Longevity
Dry Retention Basins	Deep permeable soils	Small	Low	High
Exfiltration Trenches	Deep permeable soils	Small	High	Low
Concrete Grid Pavers	Deep permeable soils; restricted traffic	Small	Moderate	Moderate
Vegetated Filter Strips	Low density areas	Small	Low	High if maintained
Grassed Swales	Low density areas	Small	Low	High if maintained

a. Careful attention to erosion and sediment controls is required during construction to keep sediment loads out of retention systems or failures may occur.

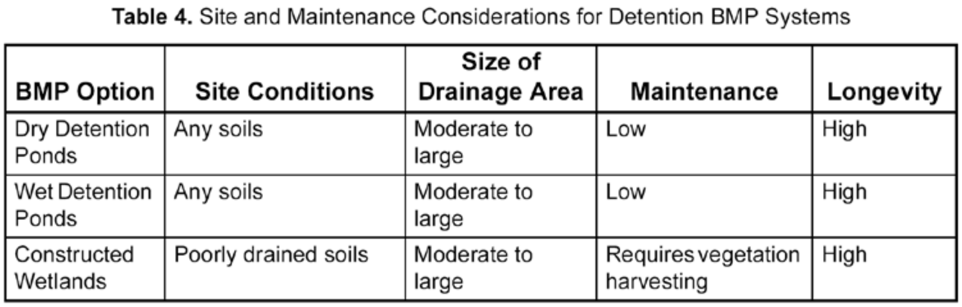


Table 4. Site and Maintenance Considerations for Detention BMP Systems

BMP Option	Site Conditions	Size of Drainage Area	Maintenance	Longevity
Dry Detention Ponds	Any soils	Moderate to large	Low	High
Wet Detention Ponds	Any soils	Moderate to large	Low	High
Constructed Wetlands	Poorly drained soils	Moderate to large	Requires vegetation harvesting	High

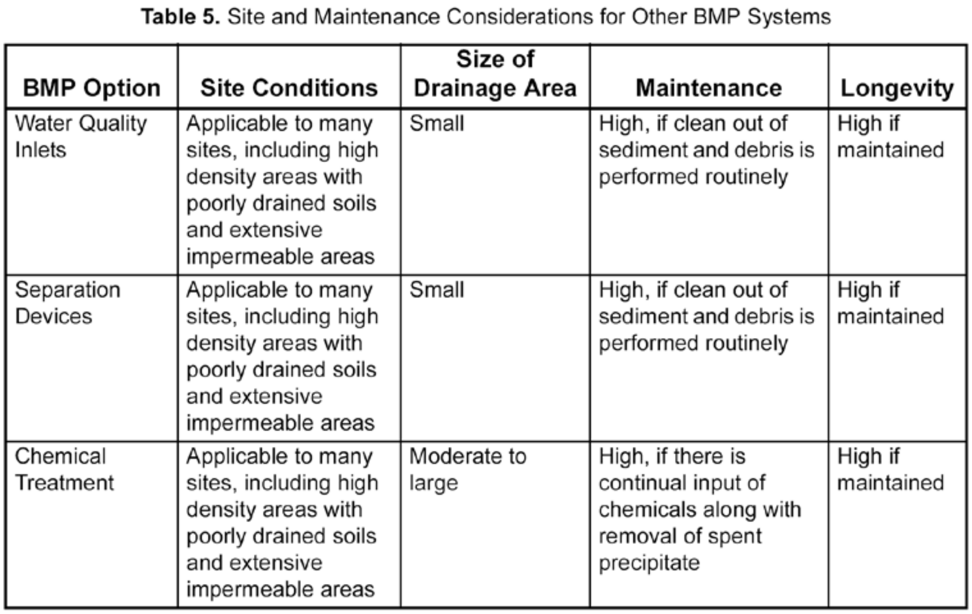


Table 5. Site and Maintenance Considerations for Other BMP Systems

BMP Option	Site Conditions	Size of Drainage Area	Maintenance	Longevity
Water Quality Inlets	Applicable to many sites, including high density areas with poorly drained soils and extensive impermeable areas	Small	High, if clean out of sediment and debris is performed routinely	High if maintained
Separation Devices	Applicable to many sites, including high density areas with poorly drained soils and extensive impermeable areas	Small	High, if clean out of sediment and debris is performed routinely	High if maintained
Chemical Treatment	Applicable to many sites, including high density areas with poorly drained soils and extensive impermeable areas	Moderate to large	High, if there is continual input of chemicals along with removal of spent precipitate	High if maintained

Table 6. BMP Options for Retrofit Control

Major Structural Controls	• Sedimentation or filtration units • Dry detention ponds (conversion to wet ponds) • Retaining walls • Sanitary sewer rehabilitation • Constructed wetlands • Chemical treatment
Minor Structural Controls	• Rip rap at pipe outfalls • Retrofit of catch basins with oil traps and/or grit traps and/or filters • Trash racks • Curb inlet filters • Oil-grit and oil-water separators • Exfiltration trenches and/or buffer strips • Grassed swales
Major Nonstructural Controls	• Bank stabilization of waterways • Dredging in drainage ways • Water body cleanup effort • Open space acquisition • Ordinances and regulatory programs • Conservation, recycling, and source control programs
Minor Nonstructural Controls	• Enhanced street sweeping • Parking lot sweeping • Storm drain stenciling • Vegetation control in main ditches
Preventative/Maintenance Oriented Controls	• Increased frequency of catch basin and manhole cleaning • Turf and landscape management • Road maintenance • Ditch/creek cleaning
Public Awareness and Education	• Litter prevention • Trash and debris dumping prevention • Toxic materials/oil and grease dumping prevention
Enhanced Enforcement	• Construction activities • Illegal dumping and disposal • Commercial non-stormwater discharges
Continuing Assessment	• Sediment sampling • Dry weather monitoring • Wet weather monitoring • Facility, appurtenances, and other BMP inspection

H. *Conclusions*

Stormwater management activities have evolved from singular practices that addressed individual needs and crisis situations to multiple objective programs that manage water supply and conservation, and preservation of surface water and natural systems. As stormwater runoff is a major source of pollution to our wetlands, rivers, lakes, and estuaries, local governments must take responsibility for its control. No water quality control program should be implemented in a vacuum. An understanding of the origin and causes of nonpoint source pollution is essential to the development of comprehensive, effective, and efficient control practices. BMPs should be integrated into multiple objective programs to ensure that watershed goals are cooperatively met. In many cases, BMP implementation can provide supplemental benefits for local citizens, like the use of reuse ponds for irrigation. Environmental and aesthetic enhancements can be achieved through thoughtful design, conscientious maintenance, and creative landscaping

V. REFERENCE OF TYPICAL TERMS

The following definitions are used by the Florida Department of Environmental Protection and the State Water Management Districts to clarify intent in implementing permitting programs pursuant to Part IV, Chapter 373, F.S. Many of these definitions are derived directly from Chapter 373, F.S.

Annual average flow - is the long-term harmonic mean flow of the receiving water, or an equivalent flow based on generally accepted scientific procedures in waters for which such a mean cannot be calculated. For waters for which flow records have been kept for at least the last three years, “long-term” shall mean the period of record. For all other waters, “long-term” shall mean three years (unless the Department finds the data from that period not representative of present flow conditions, based on evidence of land use or other changes affecting the flow) or the period of records sufficient to show a variation of flow of at least three orders of magnitude, whichever period is less.

Appurtenant work - Any artificial improvements to a dam which might affect the safety of such dam or, when employed, might affect the holding capacity of such dam or of the reservoir or impoundment created by such dam (subsection 373.403(2), F.S.).

Aquatic plant - A plant, including the roots, which typically floats on water or requires water for its entire structural support, or which will desiccate outside of water.

Aquatic preserve - Those areas designated in part II, chapter 258, F.S. (subsection 40C-4.021(4), F.A.C.).

Artificial structure(s) - Any object constructed or installed by man which has a water management effect, including, but without limitation thereof, dikes, levees, embankments, ditches, canals, conduits, channels, culverts, and pipes.

Canal - means a trench, the bottom of which is normally covered by water, with the upper edges of its two sides normally above water.

Channel - means a trench, the bottom of which is normally covered entirely by water, with the upper edges of one or both of its sides normally below water.

Closed system - Any reservoir or works located entirely within agricultural lands owned or controlled by the user and which requires water only for the filling, replenishing, and maintaining the water level thereof (subsection 373.403(6), F.S.).

Conceptual approval permit - A surface water management permit issued by the District, approving the concept of a master plan for a surface water management system, which is binding upon the District and the permittee (subsection 40C-4.021(6), F.A.C.).

Construction - Any activity including land clearing, earth-moving or the erection of structures which will result in the creation of a system (subsection 40C-4.021(7), F.A.C.).

Control device - Element of a discharge structure which allows the gradual release of water under controlled conditions. Sometimes referred to as the bleed-down mechanism, or "bleeder".

Control elevation - The lowest elevation at which water can be released through the control device.

Dam - Any artificial or natural barrier, with appurtenant works, raised to obstruct or impound, or which does obstruct or impound, any of the surface waters of the state (subsection 373.403(1), F.S.).

Designated use - shall mean the present and future most beneficial use of a body of water as designated by the Environmental Regulation Commission by means of the Classification system used by designated government agency.

Detention - The delay of stormwater runoff prior to discharge into receiving waters.

Detention area (wet) - A water storage area with bottom elevation lower than one foot above the control elevation of the area.

Detention volume - The volume of open surface storage behind the discharge structure between the overflow elevation and control elevation.

Direct hydrologic connection - A surface water connection which occurs on an average of 30 or more consecutive days per year. In the absence of reliable hydrologic records, a continuum of wetlands maybe used to establish a direct hydrologic connection.

Discharge - To allow or cause water to flow.

Dissolved metal - shall mean the metal fraction that passes through a 0.45 micron filter.

District Water Management Plan - means the regional water resource plan developed by a governing board under s. 373.036.

Drainage basin- A subdivision of a watershed (subsection 373.403(9), F.S.).

Drainage ditch or irrigation ditch - means a man-made trench which is dug for the purpose of draining water from the land or for transporting water for use on the land and which is not built for navigational purposes

Dredging - Excavation, by any means, in surface waters or wetlands, as delineated in subsection 373.421(1), F.S. Excavation also means the excavation, or creation, of a water body which is, or is to be, connected to surface waters or wetlands, as delineated in subsection 373.421(1), F.S., directly or via an excavated water body or series of water bodies (subsection 373.403(13), F.S.).

Ecological value - The value of functions performed by uplands, wetlands and other surface waters to the abundance, diversity, and habitats of fish, wildlife, and listed species. These functions include, but are not limited to, providing cover and refuge; breeding, nesting, denning, and nursery areas; corridors for wildlife movement; food chain support; and natural water storage, natural flow attenuation, and water quality improvement, which enhances fish, wildlife and listed species utilization. (subsection 373.403(18), F.S.)

Effluent limitation - shall mean any restriction established by the Department on quantities, rates or concentrations of chemical, physical, biological or other constituents which are discharged from sources into waters of the State.

Elevation - Height in feet above mean sea level according to National Geodetic Vertical Datum (NGVD).

Enhancement - Improving the ecological value of wetlands, other surface waters, or uplands that have been degraded in comparison to their historic condition.

Estuary - A semi-enclosed, naturally existing coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with fresh water derived from riverine systems (subsection 373.403(15), F.S.).

Exceptional recreational significance - shall mean unusual value as a resource for outdoor recreation activities. Outdoor recreation activities include, but are not limited to, fishing, boating, canoeing, water skiing, swimming, scuba diving, or nature observation.

Filling- The deposition, by any means, of materials in surface waters or wetlands, as delineated in subsection 373.421(1), F.S. (subsection 373.403(14), F.S.).

Floodway - The permanent channel of a stream or other watercourse, plus any adjacent floodplain areas that must be kept free of any encroachment in order to discharge the 100 year flood without cumulatively increasing the water surface elevation more than a designated amount (not to exceed one foot except as otherwise established by the District or established by a Flood Insurance Rate Study conducted by the Federal Emergency Management Agency (FEMA)).

Florida water plan - means the state-level water resource plan developed by the department under s. 373.036.

Groundwater - means water beneath the surface of the ground, whether or not flowing through known and definite channels.

Ground cover - means the plant stratum composed of all plants not found in the canopy or sub canopy, except vines and aquatic plants.

Herbaceous wetlands - means those wetlands dominated by non-woody vegetation that have less than a 10 percent canopy coverage of trees with a diameter at breast height of greater than 4 inches.

Historic discharge - The peak rate at which runoff leaves a parcel of land by gravity in an undisturbed/natural state, or the legally allowable discharge in effect at the time of permit application.

Hydric soils - means soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part of the soil profile.

Hydric soil indicators - means those indicators of hydric soil conditions as identified in *Soil and Water Relationships of Florida's Ecological Communities* (Florida Soil Conservation ed. Staff 1992).

Hydrologic indicators - Physical indicators of inundation or saturation which can be easily observed in the field. This includes water marks or stains on structures or woody vegetation, elevated lichen lines and moss collars on trees, algal mats, vegetated tussocks or hummocks, drift lines and rafted debris, and morphological plant adaptations such as adventitious roots or enlarged (buttressed) trunks. For more information on hydrologic indicators please refer to *The Florida Wetlands Delineation Manual,* 1995, Florida Department of Environmental Protection.

Hydrologically sensitive area - Wetlands and those geographical areas which are specifically designated as hydrologically sensitive areas by the Board because of the importance of the hydrology and hydraulics of the area in meeting the Legislative policy contained in section 373.016, F.S. (subsection 40C-4.021(15), F.A.C.).

Impervious - Land surfaces which do not allow, or minimally allow, the penetration of water; included as examples are building roofs, normal concrete and asphalt pavements, and some fine grained soils such as clays.

Impoundment - Any lake, reservoir, pond, or other containment of surface water occupying a bed or depression in the earth's surface and having a discernible shoreline (subsections 373.403(3) and 373.019(14), F.S.).

Incidental site activities - The following activities in uplands which are conducted as part of the construction of a system proposed in an environmental resource permit application: land clearing; grading; excavation of borrow areas for on-site grading; erosion and sediment control measures; road and building subgrade construction (excluding foundation construction); unpaved access road construction; utility installation; fence installation; construction trailer installation; and other similar activities.

Insect control impoundment dikes - means artificial structures, including earthen berms, constructed and used to impound wetlands or other surface waters for the purpose of insect control.

Inundation - means a condition in which water from any source regularly and periodically covers a land surface.

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

Littoral zone - In reference to stormwater management systems, this phrase shall mean that portion of a wet detention pond which is designed to contain rooted aquatic plants.

Mitigation - An action or series of actions to offset the adverse impacts that would otherwise cause a regulated activity to fail to meet the criteria. Mitigation usually consists of restoration, enhancement, creation, preservation, or a combination thereof.

Mitigation bank - A project permitted under section 373.4136, F.S., undertaken to provide for the withdrawal of mitigation credits to offset adverse impacts authorized by a permit under part IV of chapter 373, F.S. (subsection 373.403(19), F.S.)

Mitigation bank permit - a permit issued to a banker to construct, operate, manage and maintain a mitigation bank.

Natural background - shall mean the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered waterbody or on historical pre-alteration data.

Nonregulated use - means any use of water which is exempted from regulation by the provisions of a stormwater rule.

Normal pool - Elevation of average or sustained wet season water levels in a wetland. It is generally used to establish wetland control elevations.

Operation permit - means a permit issued authorizing the operation and maintenance of a surface water management system in accordance with the terms and conditions of the permit.

Outstanding Florida Waters - shall mean waters designated by the Environmental Regulation Commission as worthy of special protection because of their natural attributes.

Overflow elevation - Design elevation of a discharge structure at which, or below which, water is contained behind the structure, except for that which leaks out, or bleeds out, through a control device down to the control elevation.

Permanent pool - That portion of a wet detention pond which normally holds water (e.g., between the normal water level and the pond bottom).

Pollution - shall mean the presence in the outdoor waters of the State of any substances, contaminants, or man-made or man-induced alteration of the chemical, physical, biological or radiological integrity of water in quantities or levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property, including outdoor recreation.

Project area - The area being modified or altered in conjunction with a proposed activity requiring a permit (subsection 40C-4.021(22)).

Reasonable-beneficial use - means the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest.

Regulated activity - The construction, alteration, operation, maintenance, abandonment or removal of a system regulated pursuant to part IV, chapter 373, F.S.

Remove or Removal - Cessation of use and maintenance activities for a system, or part of a system, accompanied by elimination of all or part of the system (subsection 40C-4.021(23), F.A.C.).

Reservoir - Any artificial or natural holding area which contains or will contain the water impounded by a dam (subsection 373.403(4), F.S.).

Restoration - Converting back to a historic condition those wetlands, surface waters, or uplands which currently exist as a land form which differs from the historic condition.

Retention - The prevention of stormwater runoff from direct discharge into receiving waters; included as examples are systems which discharge through percolation, exfiltration, filtered bleed-down and evapotranspiration processes.

Reuse pond - that storage area used to retain runoff waters that are used for irrigation. This is also called an irrigation pond.

Riprap - means a sustaining wall made to reduce the force of waves and to protect the shore from erosion and consists of unconsolidated boulders, rocks, or clean concrete rubble with no exposed reinforcing rods or similar protrusions.

Saturation - means a water table six inches or less from the soil surface for soils with a permeability equal to or greater than six inches per hour in all layers within the upper 12 inches, or a water table 12 inches or less from the soil surface for soils with a permeability less than six inches per hour in any layer within the upper 12 inches.

Seasonal High Water Level (SHWL) - Elevation of surface water within a wetland which occurs during typical storm events in the wet season. The SHWL is above the normal pool elevation but can be lower than the seasonal high water *table* within the surrounding upland soil. The SHWL is typically found at or near the wetland boundary.

Seasonal High Water Table (SHWT) - The highest average depth of saturation during the wet season. (Refer to pages CA-1 through CA-6 for a discussion of the methods and indicators used to establish the SHWT.) “Species of Special Concern” means those animal species listed in Rule 68A- 27.005, F.A.C.

State Water Quality Standards - means water quality standards adopted pursuant to Chapter 403, F.S.

Stormwater management system - A system which is designed and constructed or implemented to control discharges which are necessitated by rainfall events, incorporating methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water to prevent or reduce flooding, over drainage, environmental degradation, and water pollution or otherwise affect the quantity and quality of discharges from the system (subsection 373.403(10), F.S.).

Stream - Any river, creek, slough, or natural watercourse in which water usually flows in a defined bed or channel. It is not essential that the flowing be uniform or uninterrupted. The fact that some part of the bed or channel shall have been dredged or improved does not prevent the watercourse from being a stream (subsection 373.019(11), F.S.).

Surface water - Water upon the surface of the earth, whether contained in bounds created naturally or artificially or diffused. Water from natural springs shall be classified as surface water when it **exits** from the spring onto the earth's surface (subsection 373.019(10), F.S.).

Surface water management system or system - A stormwater management system, dam, impoundment, reservoir, appurtenant work, or works, or any combination thereof. The terms "surface water management system" or "system" include areas of dredging or filling, as those terms are defined in subsections 373.403(13) and 373.403(14), F.S.

Swale - means a man-made trench which that both infiltrates and transports water.

Water management district - means any flood control, resource management, or water management district operating under the authority of a government body.

Water quality criteria - shall mean elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses. (30) “Water quality standards” shall mean standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, the Florida antidegradation policy, and the moderating provisions contained in this rule and in Chapter 62-4, F.A.C., adopted pursuant to Chapter 403, F.S.

Waters - shall be as defined in Section 403.031(13), Florida Statutes.

Watershed - The land area which contributes to the flow of water into a receiving body of water (subsection 373.403(12), F.S.).

Wet detention - means the collection and temporary storage of stormwater in a permanently wet impoundment in such a manner as to provide for treatment through physical, chemical, and biological processes with subsequent gradual release of the stormwater.

Wetlands - Those areas that are inundated or saturated by surface or ground water at a frequency and a duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Soils present in wetlands generally are classified as hydric or alluvial, or possess characteristics that are associated with reducing soil conditions (subsection 373.019(17), F.S.) The landward extent of wetlands is delineated pursuant to sections 62-340.100 through 62-340.550, F.A.C., as ratified by section 373.4211, F.S., (subsection 40C-4.021(30), F.A.C.)

Zone of mixing or mixing zone - shall mean a volume of surface water containing the point or area of discharge and within which an opportunity for the mixture of wastes with receiving surface waters has been afforded.

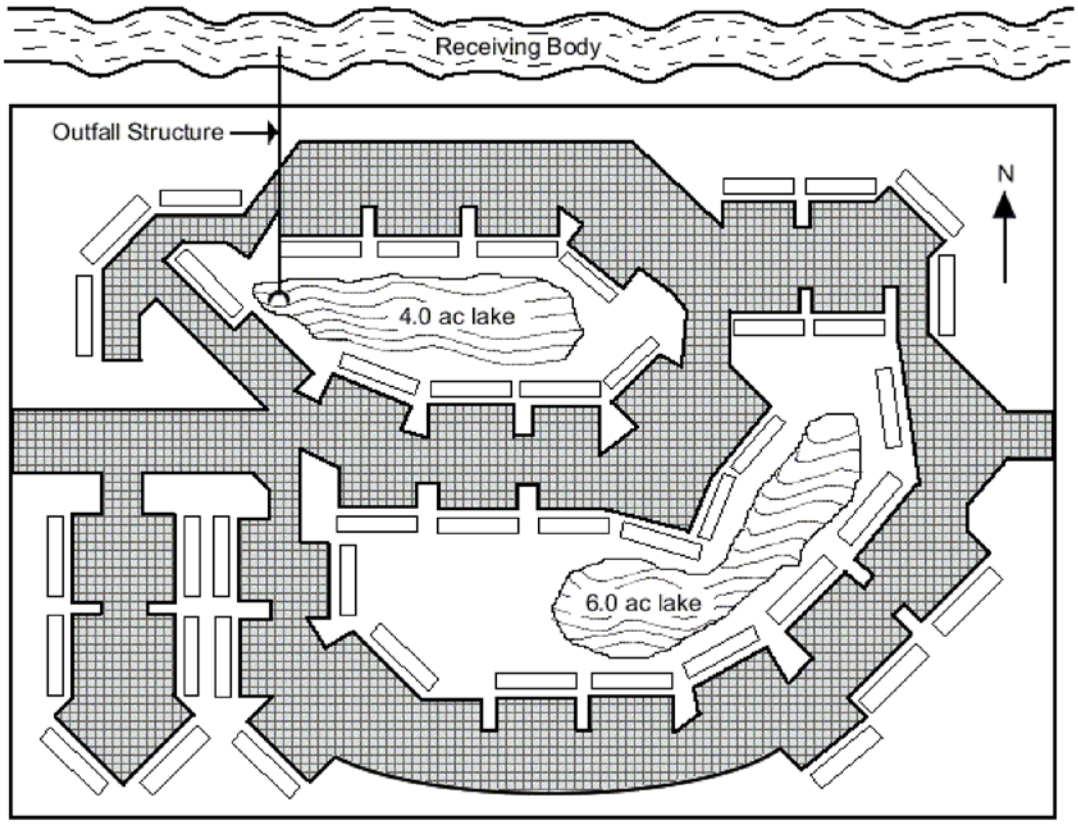
VI. STORMWATER MANAGEMENT DESIGN EXAMPLE

Project Design Example

The following example was adapted from SFWMD's Environmental Resource Permit Information Manual *Volume IV.* The example illustrates how the rules, technical criteria, and design aids presented in earlier parts might be used during the course of designing a surface water management system for a residential development. What is presented does not constitute additional rule criteria, and should not be used in lieu of the criteria or in a manner that is inconsistent with duly adopted rules.

Practitioners are cautioned that this example is not intended to provide guidance for all potential design aspects of a residential development's surface water management system. Specific project variables encountered – such as topography, soils, existing development, receiving body location, receiving body water quality classification, development density, and wetland preserve areas – may dictate much more detailed or elaborate analyses.

SITE PLAN VIEW
(N.T.S.)



I. Given

A. Acreage

1. Total = 95.0 ac

2. Impervious

   a. Buildings (roofs) = 9.3 ac

   b. Roads and parking = 41.7 ac

3. Lakes = 10.0 ac

4. Pervious = 34.0 ac

B. Minimum elevations

1. Roads and parking = 9.0' NGVD

2. Floors = 11.5' NGVD

C. Design storm allowable discharge has been determined to be 37 cfs.

D. Water level elevations

1. Average wet season water table in the vicinity of the lakes = 5.5' NGVD.

2. Receiving body water level has been determined not to affect discharge rates.

(Note: Proposed minimum road grade (9.0' NGVD) is more than 2 ft above the average wet season water table, or control elevation, of 5.5' NGVD. This is a criteria which is occasionally overlooked in initial designs.)

E. Rainfall amounts (24-hour)

1. Roads (10-year) = 9.0 in.

2. Design (25-year) = 11.0 in. (this will be adjusted to a 72-hour event later)

3. Floors (100-year) = 14.0 in. (this will be adjusted to a 72-hour event later)

II. Design Criteria

A. Quality

1. Since this is proposed as a wet detention system, then whichever is the greater of:

   a. The first inch of runoff from the entire site, or

   b. The amount of 2.5 inches times the percentage of imperviousness.

2. If this residentially-zoned site were discharging directly into sensitive receiving waters (example: Outstanding Florida Waters), then it might have to provide at least 0.5 inch of dry detention or retention pretreatment. (This will be discussed later in more detail.)

3. Any detention system shall be designed to discharge not more than 0.5 inch of the detained volume per day. A V-shaped configuration is desirable.

B. Quantity

1. The allowable peak discharge is 37 cfs during a 25-year 3-day storm.

2. First floors are desired to be no lower than elevation 11.5' NGVD.

3. Roads and parking are desired to be no lower than elevation 9.0' NGVD.

III. Computations

A. Quality

1. Compute the first inch of runoff from the developed project:

   = 1 in. x 95 ac x (1 ft/12 in.)

   = <u>7.9 ac-ft</u> for the first inch of runoff.

2. Compute 2.5 inches times the percentage of imperviousness:

   a. Site area for water quality pervious/impervious calculations <u>only</u>:

      = Total project - (water surface + roof)

      = 95 ac - (10 ac + 9.3 ac)

      = 95 ac - 19.3 ac

      = <u>75.7 ac</u> of site area for water quality pervious/impervious.

b. Impervious area for water quality pervious/impervious calculations only:

= (Site area for water quality pervious/impervious) - pervious

= 75.7 ac - 34.0 ac

= 41.7 ac of impervious area for water quality pervious/impervious.

c. Percentage of imperviousness for water quality:

= (Impervious area for water quality/Site area for water quality) x 100%

= (41.7 ac/75.7 ac) x 100%

= 55% impervious

d. For 2.5 inches times the percentage impervious:

= 2.5 in. x 0.55

= 1.38 in. to be treated.

e. Compute volume required for water quality detention:

= inches to be treated x (total site - lakes)

= 1.38 in. x (95 ac - 10 ac) x (1 ft/12 in.)

= 9.8 ac-ft required detention storage.

3. Since the 9.8 ac-ft are greater than the 7.9 ac-ft computed for the first inch of runoff, the volume of 9.8 ac-ft controls.

(Note: The system proposed is wet detention, so no volume reductions are possible.)

Now design a reuse pond based on the runoff from 3 inches of rainfall.

1. The design calls for the runoff from the effective impervious area, or that area that will contribute runoff from the 3-inch rain event. It is calculated by dividing the impervious area (minus the lake) from the total with the understanding that runoff from the pervious area will not be transported to the impervious areas. This assumption must be designed into the project or tested.
2. Thus the size of the reuse pond in acre feet is
   (3in/12in/foot)(95Acres)(51/95) = 12.8 acre-feet.
3. The effective impervious area in this case is the runoff coefficient for the total area and assumes no initial abstraction. The runoff coefficient is 0.54.

B. SCS Curve Number

1. Even though the control elevation is 5.5' NGVD, it is assumed that the water table will vary from 5.5' NGVD at the lakes to about 7' NGVD at the project boundaries. Consequently an average site water table elevation of 6.25' NGVD will be assumed.

2. The average site finished grades will vary from the lowest inlets in the parking lots (9.0' NGVD), to a little above the 11.5' NGVD floor elevations (say 12' NGVD). Therefore, average site grade elevation will be 10.5' NVD.

3. The average depth to water table will be

   = average site grade elevation - average site water table elevation

   = 10.5' NGVD - 6.25' NGVD

   = <u>4.25 ft</u>; 4 ft is the maximum depth of percolation assumed possible in three days for the soils on this site.

4. From the soil storage table, assuming the 25% compaction and 4 ft to the water table, up to 8.18 inches of moisture can be stored in the soil under pervious areas.

5. Compute available soil storage

   = storage available x pervious areas

   = 8.18 in. x 34 ac x 1 ft/12 in.

   = <u>23.2 ac-ft</u> available soil storage onsite.

6. Convert available soil storage to site-wide moisture storage, S

   S = available soil storage onsite/site area

   = ((23.2 ac-ft)/(95 ac)) x (12 in./1 ft)

   = <u>2.93 in.</u> of site-wide soil storage, S

7. SCS Curve Number, CN

   CN = 1000/(S + 10)

   = 1000/(2.93 + 10)

   = <u>77</u>: SCS Curve Number

C. Project surface storage

1. Assumptions

   a. Lake storage begins at a control elevation which is the given 5.5' NGVD.

   b. Lake storage is vertical over the 10 ac of lake surface area.

   c. Site storage is linear, starting at the minimum road elevation of 9.0' NGVD up through 12.0' NGVD.

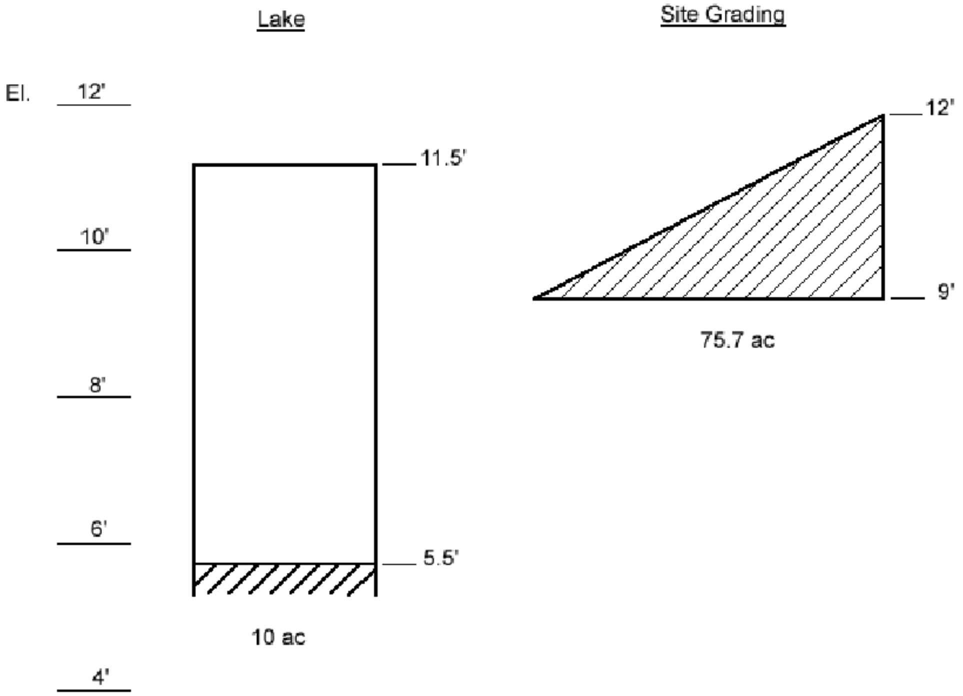
   d. Area of developed site grading:

      = Total area - (lakes + buildings)

      = 95 ac - (10 ac + 9.3 ac)

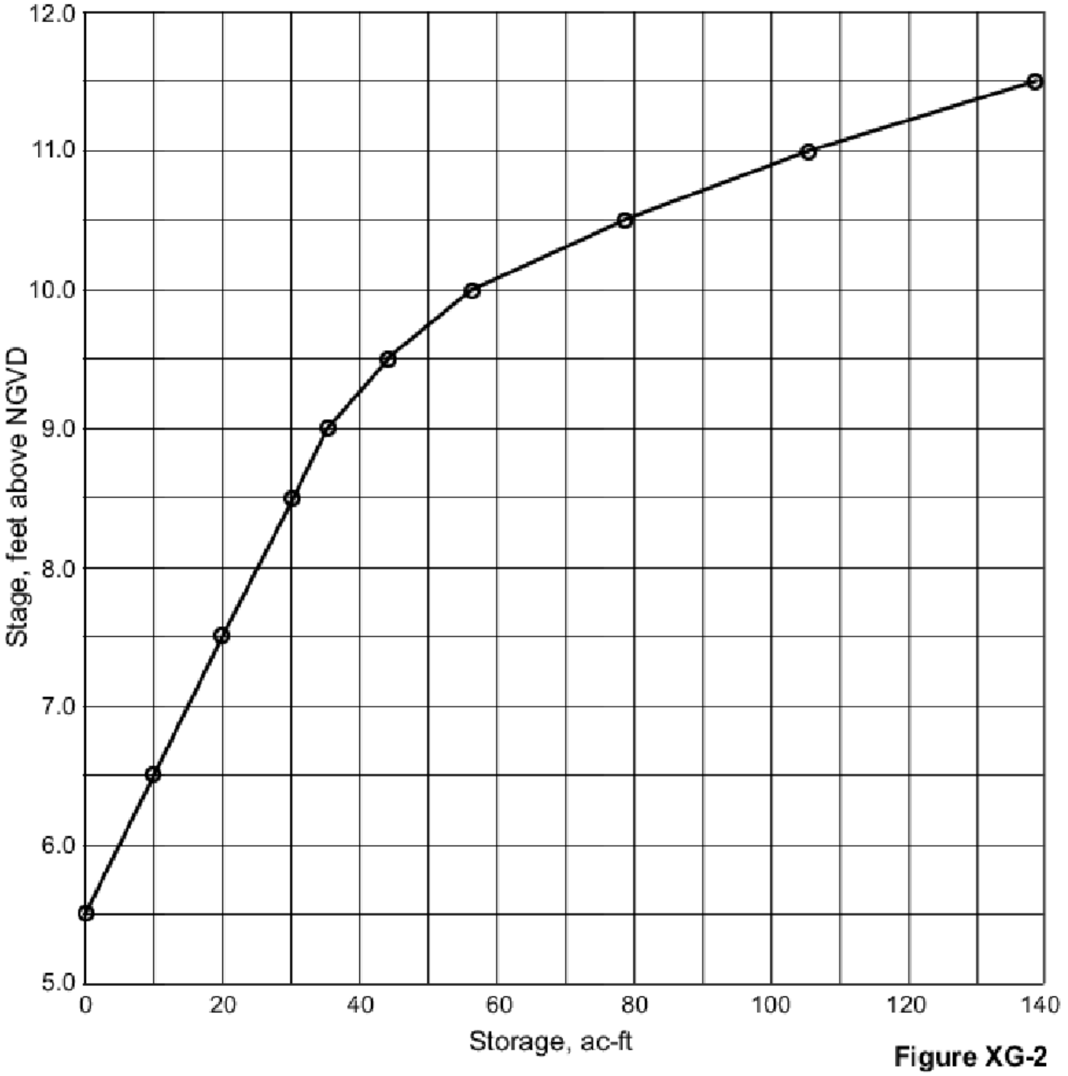
      = <u>75.7 ac</u> for developed site grading.

2. Stage-Storage Schematic Diagrams



3. Stage-storage curve data

	Storage		
Stage (ft NGVD)	Lake (ac-ft)	Site Grading (ac-ft)	Total (ac-ft)
5.5	0' x 10 ac = 0	0	0
6.5	1' x 10 ac = 10	0	10
7.5	2' x 10 ac = 20	0	20
8.5	3' x 10 ac = 30	0	30
9.0	3.5' x 10 ac = 35	0	35
9.5	4' x 10 ac = 40	((0.5/3) x 75.7 ac) x (0.5 ft/2) = 3.2	43.2
10.0	4.5' x 10 ac = 45	((1.0/3) x 75.7 ac) x (1.0 ft/2) = 12.6	57.6
10.5	5' x 10 ac = 50	((1.5/3) x 75.7 ac) x (1.5 ft/2) = 28.4	78.4
11.0	5.5' x 10 ac = 55	((2.0/3) x 75.7 ac) x (2.0 ft/2) = 50.5	105.5
11.5	6' x 10 ac = 60	((2.5/3) x 75.7 ac) x (2.5 ft/2) = 78.8	138.8



MULTI-FAMILY RESIDENTIAL SITE
STAGE - STORAGE CURVE

Figure XG-2

D. Control structure weir crest elevation.

1. Set the crest high enough to store the required quality volume quantity of 9.8 ac-ft.

2. From the stage-storage curve, the weir crest should be set at elevation 6.5' NGVD.

E. Control structure weir crest length.

1. Runoff from the design storm (25-year 3-day).

   a. Rainfall amount for a three-day event

      = 1-day rainfall x 1.359

      = 11.0 in. x 1.359

      = 14.95 in. rainfall in three days.

   b. Runoff in inches (Q)

      $Q = (P - (0.2 \times S))^2 / (P + (0.8 \times S))$

      $= \frac{(14.95 \text{ in.} - (0.2 \times 2.93 \text{ in.}))^2}{(14.95 \text{ in.} + (0.8 \times 2.93 \text{ in.}))}$

      $= (14.95 \text{ in.} - 0.59 \text{ in.})^2 / (14.95 \text{ in.} + 2.34 \text{ in.})$

      $= (14.36 \text{ in.})^2 / 17.29 \text{ in.}$

      = 11.9 in. of runoff from the 25-year 3-day storm.

   c. Runoff volume

      = inches of runoff x site area

      = 11.9 in. x 95 ac x 1 ft/12 in.

      = 94.2 ac-ft runoff volume.

2. The zero-discharge stage corresponding to 94.2 ac-ft is 10.8' NGVD.

3. The maximum design head would then be 10.8' NGVD - 6.5' NGVD = 4.3'. Therefore, try a design head of 4.0 ft for sizing the weir.

4. Compute weir length.

   a. Basic equation is $Q = 3.13LH^{1.5}$

   b. Rearranged, $L = Q/(3.13 \times (H)^{1.5})$

      Where: L = weir length, ft
      Q = design discharge, cfs
      H = design head on weir, ft

c. If Q = 37 cfs and H = 4 ft, then

$L = 37 \text{ cfs}/(3.13 \times (4 \text{ ft})^{1.5})$

$= 37/(3.13 \times 8.0)$

$= 37/25.04$

= say, 1.5 ft weir length.

F. Size the control structure detention discharge weir.

1. Criteria

   a. A V-notch is desirable.

   b. A triangular or circular orifice may be necessary.

   c. Size the weir (or orifice), to discharge no more than 0.5 inch of the detention volume in 24 hours.

2. Volume to be discharged in the first 24 hours is 0.5 inch of the required detention.

   = 0.5 in. x (total site - lakes)

   = 0.5 in. x (95 ac - 10 ac) x (1 ft/12 in.)

   = 3.5 ac-ft.

3. Design head

   = weir crest elevation - control elevation

   = 6.5' NGVD - 5.5' NGVD

   = 1 ft.

4. From the "Required V-Notch Size" design aid, for a total head of 1 ft and a desired detention volume of 3.5 ac-ft to be discharged in 24 hours, an angle of about 120 degrees is required.

   This would result in a V-notch weir with a width at elevation 6.5' NGVD greater than the 1.5 ft required for the sharp-crested weir. For various reasons, it is deemed unacceptable to alter other segments of the project until all reasonable control structure design possibilities have been exhausted.

   One approach is to utilize the 1.5-ft long sharp-crested weir and a V-notch weir with an angle considerably less than the 120° required to obtain the maximum discharge rate of the required quality detention volume. This will result in a maximum discharge rate less than that allowed.

   Since the minimum acceptable V-notch invert angle is 20°, the structure will incorporate that feature.

5. In order to avoid culvert control of the discharge, the outfall pipe from the control structure to the receiving body is recommended to be sized so as to pass the allowable design flow at about one-half of the estimated design head. For this project, the design head is four feet, so the culvert will be sized to pass 37 cfs at two feet of head along about 400 l.f. of circular concrete pipe flowing full. From other sources, a 30" diameter culvert should be sufficient.

6. The outfall structure will consist of a baffle, a 20° V-notch weir, a 1.5 ft long sharp-crested weir, and 400 l.f. of RCP culvert, as shown in Figure XG-3.

IV. Check storm stages and discharges.

A. Minimum building floor elevation.

1. The rainfall of the 100-year 3-day storm

= (1-day amount) x 1.359

= 14.0 in. x 1.359

= 19.0 in.

2. Inches of runoff, Q

$= (P - (0.2 \times S))^2 / (P + (0.8 \times S))$

$= (19.0\text{ in.} - (0.2 \times 2.93\text{ in.}))^2 / (19.0\text{ in.} + (0.8 \times 2.93\text{ in.}))$

$= (19.0\text{ in.} - 0.6\text{ in.})^2 / (19.0\text{ in.} + 2.3\text{ in.})$

$= (18.4\text{ in.})^2 / 21.3\text{ in.}$

= <u>15.89 in.</u> of runoff.

3. Volume of runoff

= (in. of runoff) x (project area)

= 15.89 in. x 95 ac x 1 ft / 12 in.

= <u>125.8 ac-ft</u> required storage (zero discharge).

4. From the stage-storage curve, 125.8 ac-ft corresponds to an elevation of 11.3' NGVD. Since the proposed minimum floor elevation is 11.5' NGVD,

<u>the proposed minimum floor is acceptable.</u>

B. Allowable peak discharge. This is check by hand calculations or by a computer program. Either way will produce a peak discharge of about 35 cfs and the allowable is 37 cfs, so the <u>design proposed outflow structure is acceptable or adequate</u>.

C. The outflow structure and some examples of iso-rainfall curves follow.

MULTI-FAMILY RESIDENTIAL SITE OUTFALL STRUCTURE
(N.T.S.)

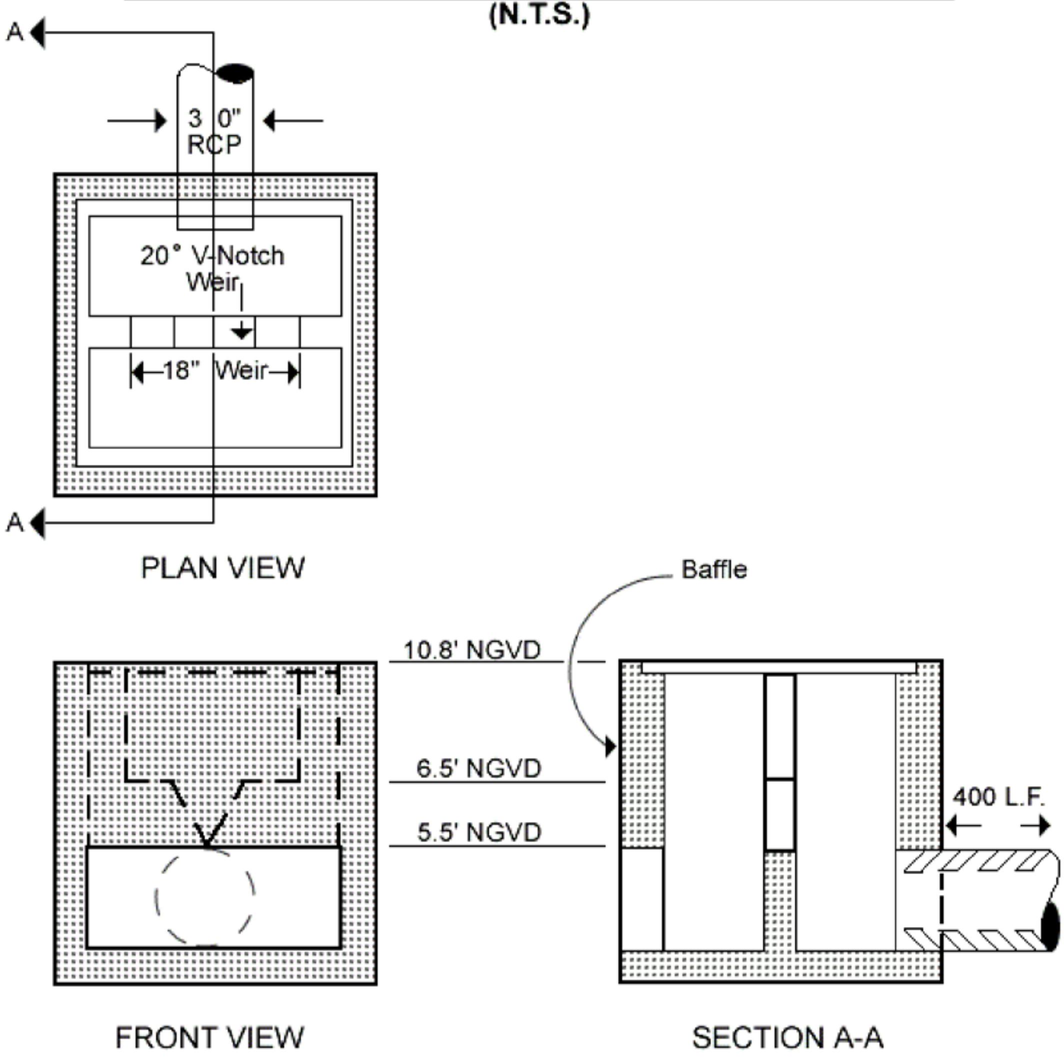


Figure XG-3

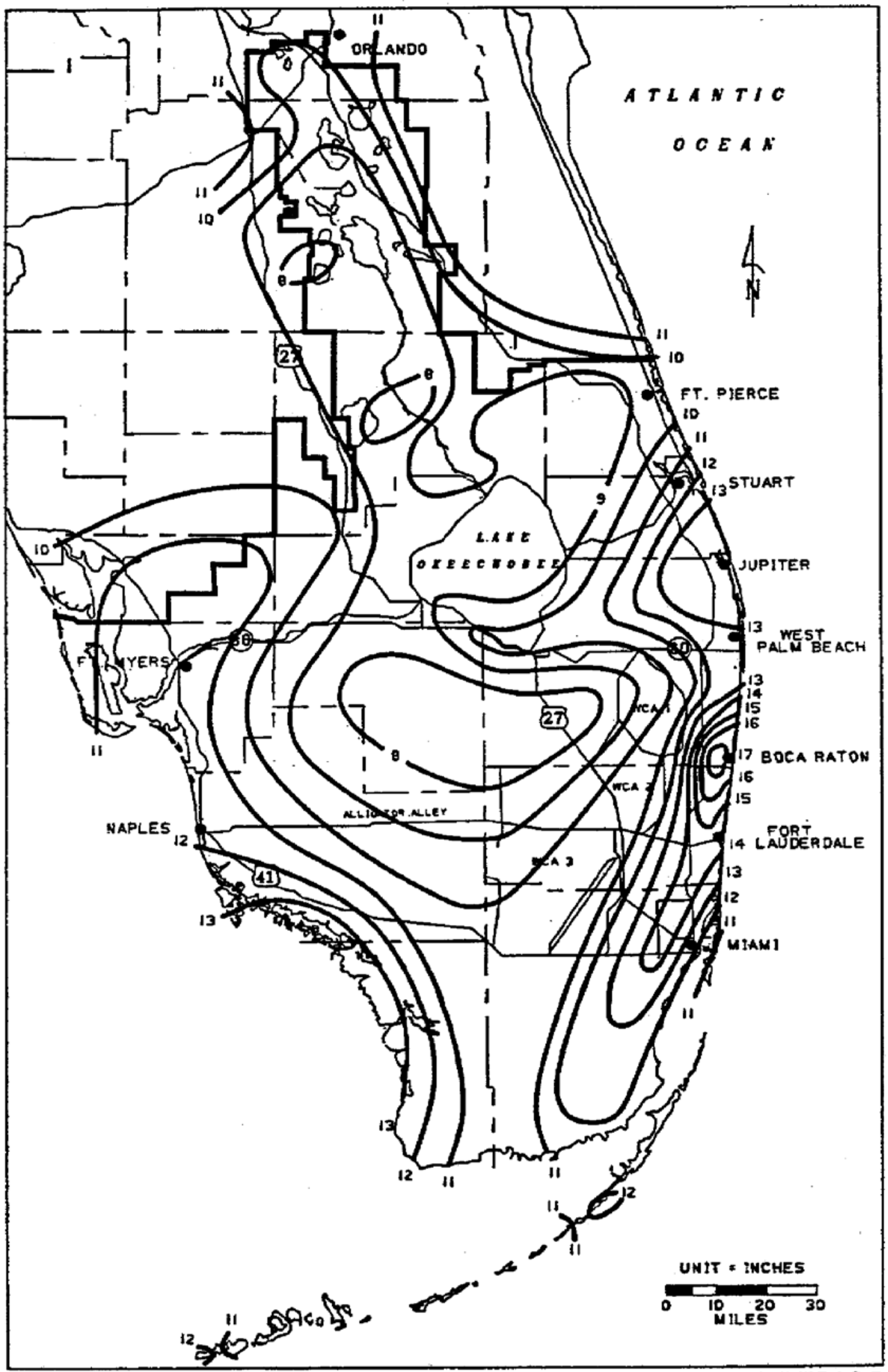


FIGURE C-8. 3-DAY RAINFALL: 25-YEAR RETURN PERIOD

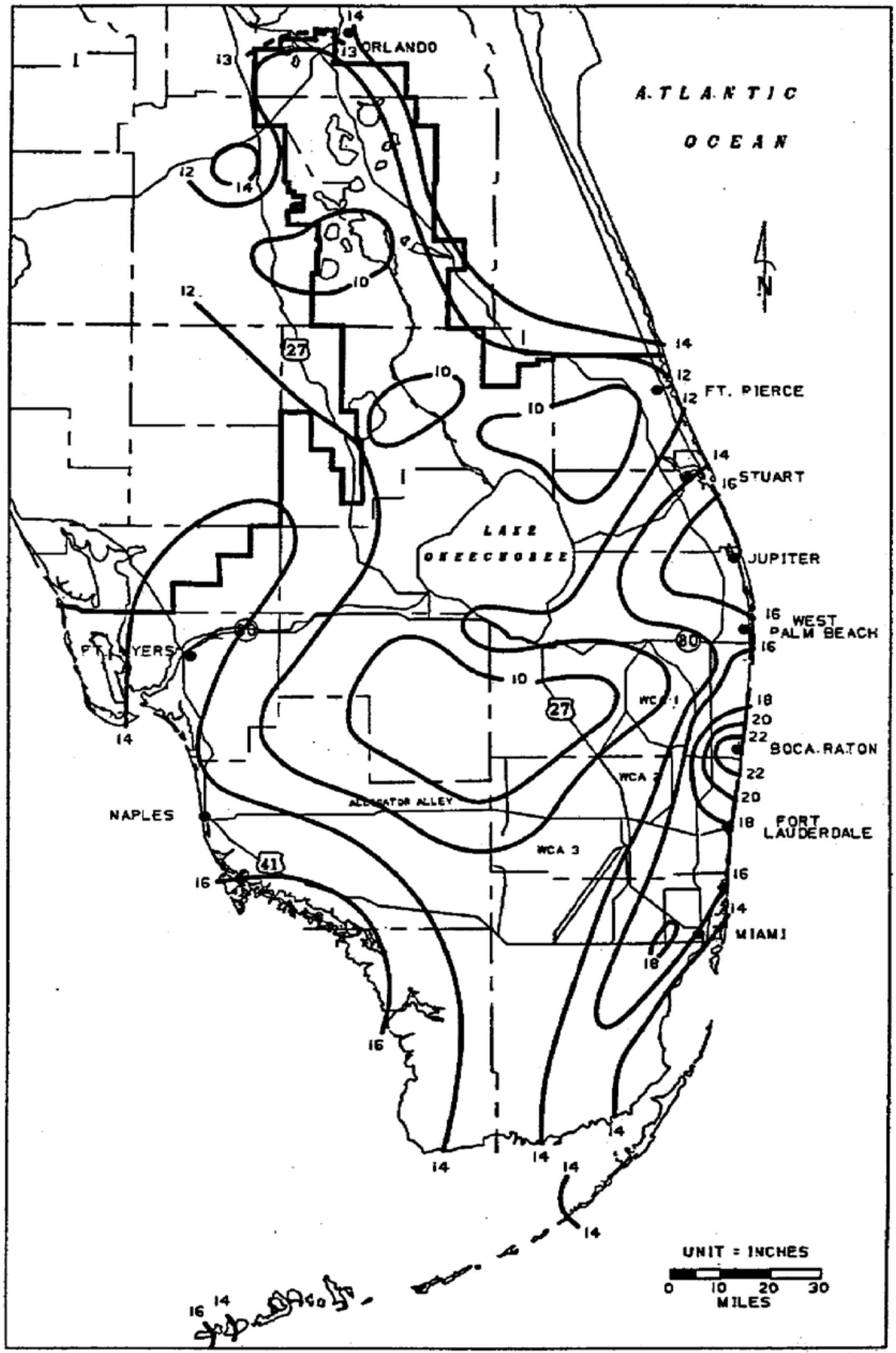


FIGURE C-9. 3-DAY RAINFALL: 100-YEAR RETURN PERIOD

Storm Water Management Examination

After you have completed answering all of the questions, go back and check your work. Make certain that you have marked only one answer for each question. There is only one correct answer to each question. Make certain that you have answered each question. Any question that is left blank will be counted as incorrect.

A score of 70% is required to complete the course. Failing to achieve a 70% score all your answers will be erased. You will have three opportunities to achieve a passing grade. Failing to score a passing grade on the third attempt will block you from further attempts and your course fee returned to you.

Once you have successfully completed exam you will be able to print out your completion certificate. We suggest you file it electronically or print it out should you be audited by your licensure board for compliance with continuing education requirements. At that time you will also be able to compare your answers to the school answers on questions you may have missed.

1. Which of the following is considered a non-point source pollution?
    a. Overland flow runoff from fertilized lawns in a residential development
    b. Treated wastewater from an industrial plant
    c. A permitted solid waste landfill
    d. Gasoline leaks from an underground storage tank at a gas station

2. What information is required to establish a water budget?
    a Rainfall
    b. Evaporation
    c. Infiltration
    d. All of the above

3. What is the likelihood of a I00 year flood or greater event will occur in a given year?
    a. 1/10
    b. 1/50
    c. 1/100
    d. 1/365

4. As more land is developed in a given watershed, what are the typical results?
    a. An increase in open space
    b. An increase in impervious area
    c. A decrease in peak flow runoff rates
    d. An increase in infiltration and a decrease in runoff volumes

5. Based on a yearly hydraulic balance, what would be the total rainfall excess, in inches, for a I-acre site with an average annual rainfall of 54 inches, with 10 inches of infiltration (including initial abstraction), 30 inches of evapotranspiration (evaporation and transpiration combined).
    a. 14 inches
    b. 24 inches
    c. 10 inches
    d. None of the above

6. Given a 12 acre site, with and average annual rainfall of 60 inches, and a runoff coefficient (C) of .50, what would be the total average annual rainfall excess for the site?
    a 12 acre-ft/year
    b. 6 acre-ft/year
    c. 30 acre-ft/year
    d. 2.5 acre-ft/year

7. Why is the interevent dry period and antecedent moisture condition for a given site important when considering a stormwater management system?

    a. Rainfall excess calculations will be affected
    b. Storm events durations will be different based on the interevent dry period chosen.
    c. Infiltration volumes are calculated based on residence time between storm events
    d. All of the above

8. For the city of Jacksonville, Florida, and using the information given within this package, what is the rainfall intensity for a 50-year storm event with a duration of 3 hours?

    a. 2.0 inches/hour
    b. 3.0 inches/hour
    c. 1.5 inches/hour
    d. 3.5 inches/hour

9. What is the total amount of rainfall expected from a 24-hour storm event with an average intensity of 0.30 inches/hour?
    a 1 inch
    b. 7.2 inches
    c. 8.0 inches
    d. 10 inches

10. Using the Rational Method for peak: discharge, find the peak: discharge for an area of 10 acres with a runoff coefficient of 0.30 and an average rainfall intensity of 1.50 inches/hour.
    a. .91 cfs
    b. .81 cfs
    c. 4.5 cfs
    d. 1.91 cfs

11. Using the SCS Curve Number Method, and given a rainfall event of 5 inches and a SCS Curve number of 55 for a given site, what would the predicted direct runoff be?

    a. 5 inches
    b. 2.75 inches
    c. 1 inch
    d. 55 inches

12. You have been asked to design a reuse pond for a l00 acre watershed with a runoff coefficient of 0.4. What is the volume in acre feet of the pond if the design criteria is 3 inches from the effective impervious area?

    a. 40
    b. 12
    c. 12
    d. 10

13. Which of the following common stormwater pollutants is not considered a heavy metal?
    a. Lead
    b. Zinc
    c. Copper
    d. Phosphorus

14. Which of the following is not considered an impairment to surface water bodies?

    a. In increase in dissolved oxygen produced by submerged aquatic plants
    b. A decrease in dissolved oxygen resulting from decaying organic matter
    c. Presence of pathogenic bacteria and viruses
    d. Increased turbidity from suspended sediment

15. Concentrations of pollutants in stormwater may typically be expressed in:

    a lbs/acre
    b. psi
    c. mg/I
    d. kg/I

16. Which of the following Stormwater Best Management Practices (BMPs) is *not.* considered a non-structural BMP?

    a. Stormwater Permitting Program
    b. Street Cleaning
    c. Public Education and Outreach Programs
    d. Constructed wetlands

17. Which of the following Stormwater Best Management Practices (BMPs) is *not* considered a structural BMP?

    a. Water Quality Inlet Filter
    b. Wet Detention Pond
    c. Dry Retention Pond
    d. Catch Basin Cleaning Program

18. For use in the design of a typical stormwater management system, what is the amount of pervious area for a 100-acre site that has 20 acres of lakes and 30 acres of buildings, roads, and parking?

    a. 100 acres
    b. 80 acres
    c. 50 acres
    d. 20 acres

19. Which is not a common consideration for implementation of a stormwater quality BMP?

    a. Maximize costs
    b. Minimize erosion
    c. Prevention of flooding roadways and property
    d. Maximize on-site storage of stormwater

20. Stormwater management systems, including all stormwater BMPs, generally require:

    a. To be installed correctly and then promptly forgotten about
    b. No compliance inspections or enforcement of permit requirements
    c. That all sediments and debris collected by a BMP should periodically be flushed out into the receiving water body to keep drains clear
    d. To be properly designed, regularly inspected, and maintained