Sarasota County

Low–Impact Development MANUAL

SARASOTA COUNTY
LOW-IMPACT DEVELOPMENT
MANUAL

SARASOTA COUNTY
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While many developments share common elements, each is unique. The information in this manual is intended only as a starting point and guidance for the reader. It should be used only in conjunction with careful consideration of applicable laws, rules, codes, ordinances, standards, and the like including, without limitation, the Americans with Disabilities Act ("laws") and interpretations of laws in effect at the time of a specific development. This manual does not change in any way the laws applicable to the planning, design, construction, operations, and maintenance of building and development projects in Sarasota County.

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CHAPTER 1: Manual Overview

1.0 PURPOSE OF MANUAL

This manual provides technical guidance and design specifications on Low Impact Development (LID) stormwater management practices for application to projects in Sarasota County, Florida. This manual is not to be used in place of - but rather as a supplement to - Sarasota County and Southwest Florida Water Management District (SWFWMD) stormwater and surface water management guidance documents regarding local design criteria and LID applicability. The guidance provided in the manual is designed to be flexible with performance criteria provided where possible. Depending on the magnitude of specific or cumulative impacts, other methods of meeting the overall water resources objectives of Sarasota County and SWFWMD will be considered. For all projects, check with local officials and other agencies to determine additional restrictions and/or surface water or watershed requirements that may apply.

LID stormwater management practices are not mandatory in Sarasota County. However, Sarasota County does encourage the use of LID practices where possible to help meet its water resource objectives. This manual is expected to be adopted by the Sarasota County Board of County Commissioners and to be incorporated by reference into the Sarasota County ordinance.

1.1 BACKGROUND

Low-Impact Development (LID) is a stormwater management approach that uses a suite of hydrologic controls (structural and non-structural) distributed throughout the site and integrated as a treatment train (i.e., in series) to replicate the natural hydrologic functioning of the landscape. Unlike conventional systems, which typically control and treat runoff using a single engineered stormwater pond located at the “bottom of the hill,” LID systems are designed to promote volume attenuation and treatment at or near the source of stormwater runoff via distributed retention, detention, infiltration, treatment, and harvesting mechanisms. The fundamental goal of applying LID concepts, design, and practice is to improve the overall effectiveness and efficiency of stormwater management relative to conventional systems, reducing total and peak runoff volumes, and improving the quality of waters discharged from the site.

A site-specific suite of LID-integrated management practices can be applied to most if not all development scenarios in Sarasota County. Regardless of the project context, LID requires consideration of the following core site planning and design objectives:

1. Preserve or conserve existing site features and assets that facilitate natural hydrologic function.

2. Minimize generation of runoff from impervious surfaces (i.e., use peak and total volume controls) and contamination (i.e., use load controls) as close to the source as possible.
3. Promote the distribution of retention, detention, treatment, and infiltration of runoff.
4. Harvest stormwater on site.
5. Minimize site disturbance and compaction of soils through low-impact clearing, grading, and construction measures.

The toolbox of LID-integrated management practices, including structural and non-structural designs, is most effective when applied in a *treatment train,* or series of complementary stormwater management practices and techniques. Typically, LID practices will not completely replace other more conventional "bottom-of-the-hill" stormwater management practices, but can be used to complement these practices and to ensure that the entire stormwater management system meets the Sarasota County and SWFWMD water resources objectives.

In addition, stormwater management that includes LID is most effective when sites are evaluated for LID compatibility as early as possible in the planning process and site conditions are considered carefully in the design and construction of each LID practice. This manual supports Sarasota County's goal of applying the LID concept and design where feasible to enhance existing stormwater management measures and reduce the adverse impacts of land development projects on the County's natural resources.

1.2 INTENDED USERS

This LID Manual is intended to be used primarily by professionals engaged in planning, designing, constructing, operating, and maintaining building and development projects in Sarasota County. These potential users include but are not limited to stormwater design engineers, stormwater utility staff, natural resource managers, planning officials and administrators, building officials, architects, landscape architects, site design specialists, and landscape operations and maintenance professionals.

1.3 ORGANIZATION OF MANUAL

In addition to this chapter, which provides an overview of LID concepts and principles and an introduction to the context for application of LID practices in Sarasota County, this manual contains three additional chapters and numerous appendices to provide guidance on the planning, design, construction, operations, and maintenance of LID projects in Sarasota County.

1.3.1 Chapter 2: Evaluating Your Site and Planning for LID

Chapter 2 focuses on the processes of site assessment, planning, and design for compatibility with LID principles and discusses mechanisms for integrating performance monitoring and feedback mechanisms at various stages of the development process. To ensure consistency with existing County land development and stormwater management rules and requirements, Chapter 2 directs users of this manual to those guidance documents by reference.

1.3.2 Chapter 3: LID Practices for Sarasota County

County-specific technical guidance on the design, construction, operations, and maintenance specifications for the following LID-integrated management practices are detailed in Chapter 3, "LID Practices for Sarasota County:"

- *Shallow Bioretention* (Section 3.1)
- *Pervious Pavements* (Section 3.2)
- *Stormwater Harvesting* (Section 3.3)
- *Greenroof Stormwater Treatment Systems* (Section 3.4)
- *Rainwater Harvesting* (Section 3.5)
- *Detention with Biofiltration* (Section 3.6)

Each section in Chapter 3 begins with an overview table that highlights the most critical information for the specific LID practice covered in that section. These overview tables provide the following:

- *Key Practice Considerations*, including intent, most suitable applications, design criteria, advantages/benefits, disadvantages/limitations, and maintenance requirements.
- *Pollutant Removal Potential* for total suspended solids, nutrients, metals, and pathogens, specified as 'High,' 'Medium,' or 'Low' relative to other LID practices, or 'No Data.'
- *Stormwater Management Suitability* for addressing water quality and volume attenuation criteria.
- *Implementation Considerations*, including land requirement, capital cost, and maintenance burden, specified as 'High,' 'Medium,' or 'Low' relative to other LID practices; residential subdivision suitability, high-density/ultra-urban suitability, drainage area requirement, shallow water table considerations, and soils criteria.
- *Other Considerations* critical for appropriate planning, design, construction, installation, operations, and maintenance of the LID practice or system.

Criteria provided in Chapter 3 are considered **minimum** standards for the design of LID treatment systems applied in Sarasota County. It is unlikely that any single LID practice will meet the SWFWMD and Sarasota County water resource objectives and it is intended that these practices be implemented in series with other LID practices and more traditional stormwater treatment practices—a treatment train approach. The stormwater treatment system (the treatment train) should be designed so that the entire system meets minimum stormwater control requirements. It is important that users of this manual consult with SWFWMD Environmental Resource Permitting criteria and the County's guidance documents on land development and stormwater management, including the County Comprehensive Plan, Land Development Regulations, and Zoning Code, for any variations to these criteria or additional standards that must be followed.

1.3.3 Chapter 4: Permitting Guide

Chapter 4 is a guide for applicants that elect to use LID treatment system design(s), and are using the LID treatment systems in conjunction with other traditional water quality treatment systems. Chapter 4 provides the acceptable minimum design criteria for the LID treatment systems to meet the current ERP Basis for Review and Sarasota County Land Development Regulation and provides design examples to illustrate how the applicant can use LID treatment systems to meet the water quality treatment requirement.

1.3.4 Appendices

Reference documents and data that provide necessary information and/or further technical guidance for the design, construction, and maintenance of Chapter 3 LID practices are provided in this manual as appendices. Examples of such appendices include rainfall tables for Sarasota County and a table of mean annual runoff coefficients.

1.4 DEMONSTRATING LID EFFECTIVENESS

Demonstrating the effectiveness of a stormwater treatment system will be a critical step in permitting a development in Sarasota County. This manual provides guidelines for demonstrating the effectiveness of LID practices for meeting the appropriate water quantity and water quality requirements and standards.

1.4.1 Water Quality

The water quality effectiveness of a stormwater treatment system that includes LID practices must be quantified based on the reduction in the average annual pollutant load. The effectiveness of the entire stormwater treatment system must be calculated by first calculating the effectiveness of each practice and then determining the effectiveness of the entire system. See Section 3.3.2.1 for an example of how this would be done for a stormwater harvesting system. Chapter 3 provides details, such as design curves, which can be used to calculate the average annual load reduction of some LID practices in Sarasota County.

1.4.2 Water Quantity

Most LID practices will provide some attenuation of peak flows and/or reduction in runoff volume during flood events. Typically, the effectiveness of the each LID practice at reducing peak runoff and/or runoff volume must be demonstrated by modifying the Natural Resource Conservation Service (NRCS) Curve Number (CN) that is used to represent the LID practice and/or the area contributing to the practice. Details on how the CN should be modified are provided in Chapter 3. In some instances it may be possible to explicitly model the structural controls of the LID practice, such as when permitting a stormwater harvesting system.

1.5 LOCAL CONTEXT

1.5.1 Sarasota County Hydrology

LID applications should be designed to mimic the natural hydrologic functioning of a site. Five hydrologic soil groups, as classified by the Natural Resource Conservation Service (NRCS), can be found in Sarasota County: Types A (well-drained), B/D (moderately well-drained when dry, not well-drained when wet), C (somewhat poorly drained), C/D (somewhat poorly drained when dry, not well-drained when wet), and D (poorly drained). A mapping of these hydrologic soil groups is provided in Figure 1-1. Note that most soils in Sarasota County are classified in the B/D hydrologic soil group due to a shallow Seasonal High Water Table (SHWT), so performance of infiltration-dependent LID applications will be constrained under wet conditions in areas with these soil types.

Land use varies widely throughout the County. Most development has occurred near the coast, with pine flatwoods dominating the eastern half of the County. Land use according to SWFWMD (2006) is mapped in Figure 1-2.

The 30 major drainage basins in Sarasota County are mapped in Figure 1-3. The basins range from 0.3-square mile (Holiday Bayou) to over 230 square miles (Big Slough).

1.5.2 Urbanization and Water Quality Standards

Florida's stormwater rules established goals for control and treatment of runoff from urban development. Criteria for the structural engineering of stormwater ponds were designed to (1) minimize flooding and, subsequently, damage to property and life by providing adequate drainage and flood control and (2) to achieve at least 85% average annual reductions in post-development pollutant loading.

While these stormwater rules and design criteria have been effective at addressing flood control and have facilitated an efficient process for managing stormwater runoff, recent research indicates that they have fallen short of achieving established water quality goals (Harper and Baker 2007). Over 200 of Florida's water bodies have been listed as impaired, meaning that they fail to achieve water quality standards established to maintain their designated use (potable water, shellfish propagation, recreation, etc.); nutrients in stormwater runoff – particularly nitrogen and phosphorus – have been identified as the cause of impairment in a majority of these waterbodies (FDEP 2006b).

1.5.3 Standards Supporting LID

Although they may not use the term "Low Impact Development" explicitly, many Sarasota County ordinances, resolutions, and policies and SWFWMD rules support the application of LID principles and design. County documents that should be referenced together with this manual for guidance on LID projects and to ensure compliance with requirements include but are not limited to the following:

- *Sarasota County Comprehensive Plan*
  - *Environment Plan* (Chapter 2)
  - *Principles for Evaluating Development Proposals in Native Habitats* (Chapter 2)
  - *Watershed Management* (Chapter 4)
  - *Future Land Use* (Chapter 9)
- *Sarasota County Environment and Natural Resource Codes* (Chapter 54, Sarasota County Code of Ordinances)
  - *Tree Protection Code* (Article XVIII)
  - *Myakka River Protection Code* (Article XXXIII)
- *Sarasota County Land Development Regulations* (Chapter 74, Sarasota County Code of Ordinances)
  - *Environmental Technical Manual* (Sec. 74-212)
  - *Site Development Design Technical Manual* (Sec. 74-212)

- *Sarasota County Zoning Regulations* (Appendix A, Sarasota County Code of Ordinances)

Regional watershed planning, floodplain protection, uplands preservation, wetlands protection, stream/watercourse protection buffers, riparian area and habitat protection; tree canopy protection, density and clustering provisions, street-width requirements, and curb and gutter requirements are among the key land use, development, and natural resource management issues that must be considered when planning for LID, a process that is discussed in Chapter 2.

1.6 TERMINOLOGY

This section defines terminology used throughout this manual. Where possible, the applicable Sarasota County Code of Ordinance definition was used.

Average Annual Load Reduction: An estimate of the long-term average reduction in annual pollutant loading provided by a stormwater management practice. This is typically expressed as a percentage.

Average Annual Rainfall: The long-term average rainfall that occurs annually (See Figure A-1)

Bioretention: The use of shallow landscaped depressions with soils, mulch, and planted vegetation intended to capture, treat, and infiltrate stormwater runoff.

Cistern: A closed reservoir or tank used for storing stormwater for stormwater harvesting.

Density: The number of residential dwelling units permitted per gross acre of land as determined by the Sarasota County Zoning regulations. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Detention: The delay of storm runoff before discharge into receiving waters. (SWFWMD 40d-Basis of Review)

Detention with Biofiltration: A landscaped depression area with a separate inlet and outlet (underdrain). Depressions are often linear and may be connected in series. Storage volume recovery of the depression is through an underdrain system. Other terms often applied to similar practices include *biodetention, bioswales*, and *vegetated swale*.

Development: A subdivision of land or a site and development as defined by these regulations; a residential mobile home park; and any other construction whether residential, commercial, industrial, office, professional, institution, or recreational except a one- or two-family dwelling on an individual lot or lots. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Directly Connected Impervious Area (DCIA): Those impervious areas that are hydraulically connected to the conveyance system and then to the basin outlet point without flowing over pervious areas.

Easement: Any strip of land created by a subdivider for public or private utilities, drainage, sanitation, or other specified uses having limitations, the title to which shall remain in the name of the property owner, subject to the right or use designated in the reservation of the servitude. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Equivalent Impervious Area (EIA): The area of a completely impervious watershed that would produce the same volume of runoff as the actual watershed.

Exotic: A species introduced to Florida, purposefully or accidentally, from a natural range outside of Florida. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Floodplain: Any land area inundated by flood events of various recurrence intervals as defined by the latest Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM), Sarasota County Basin Studies, or whichever data are, in the determination of the County, more accurate. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Greenroof: A roof area built to the specifications of this manual that includes at a minimum vegetation, media, and a waterproof membrane. To receive water quality credit, it is specifically built with a cistern or water holding system from which irrigation is provided.

Grand Tree: Any tree that has been determined by the Administrator to have the characteristics as outlined in Section 54-586, Article XVIII of the Tree Protection Code or any tree designated a Florida State Champion, United States Champion, or World Champion by the American Forestry Association.

Graywater: That part of domestic sewage that is not carried off by toilets, urinals, and kitchen drains. Graywater includes waste from the bath, lavatory, laundry, and sink, except kitchen sink waste. (Florida Statutes 381.0065 (2)(d)).

Greenroof Stormwater Treatment System: A vegetated roof with a cistern that can be used for stormwater pollution control, volume reduction, and peak flow reduction.

Harvested rainwater is runoff from a roof that is conveyed from the roof to a cistern and then used. Harvested rainwater may be used for landscape irrigation, vehicle washing, or in other outdoor non-potable applications. The Sarasota County Health Department may approve using harvested rainwater indoors for toilet flushing, urinal flushing, laundry washing, Heating, Ventilating and Air Conditioning (HVAC) make-up water, or other indoor non-potable uses provided the water is filtered, adequately disinfected, and there is adequate protection from cross-connection. The Sarasota County Health Department may approve using harvested rainwater for potable water provided the water is filtered, disinfected, and there is adequate protection from cross-connection. Harvested rainwater may not be used within the building envelope without prior approval of the Sarasota County Health Department or Sarasota County Development Services.

Invasive Species: For this manual, the acceptable listings of invasive species can be found in Sarasota County's Exotic Plant Code, Section 54-621, State regulations (Chapters 5B-57.007 and Chapter 62C-52.011 of Florida Administrative Code), the Florida Exotic Pest Plant Council's list of Category I and II invasive species as appropriate to this geographic region, as well as the following species: *Talipariti tiliaceum* (Sea hibiscus). In addition, Sarasota County reserves the right to develop additional lists of nonnative, nuisance, and invasive species.

Landscape Plant: Any native or exotic tree, shrub, or groundcover (excluding Turf). (SARASOTA COUNTY CODE OF ORDINANCES, CH. 54, ART XXXII, § 54-1023)

Littoral Zone: That portion of any lake, borrow pit, or pond measured from seasonal high water elevation in water bodies where water elevation is not controlled by structures or from the overflow elevation in water bodies where water elevation is controlled by structures to a depth of 3 feet. Littoral zones also include those areas in salt or brackish water (gulf, bay, estuary) from the mean high water elevation to a depth of 3 feet. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Low-Impact Development: A stormwater management approach that uses a suite of hydrologic controls (structural and non-structural) distributed throughout the site and integrated as a treatment train (i.e., in series) to replicate the natural hydrologic functioning of the landscape.

Native: A species whose natural range included Florida at the time of European contact (1500 AD). (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Nuisance: A species that threatens native species' abundance or diversity or the stability of an ecosystem or ecosystem process by its aggressive growth habit. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Nutrient-absorption layer: A layer included in greenroof and pervious pavement systems, which absorbs nutrients, thereby reducing the nutrient loading from the system.

Pervious Pavement: A pavement system that allows stormwater to infiltrate into the parent soil.

Plan, Site: A scaled graphic and informational representation of a specific design solution for a development phase or the entirety on which is shown an area location map; existing and proposed topography, streams, rights-of-way, easements, structures, wooded areas, and water bodies; provisions for ingress and egress; off-street parking, loading, refuse, and service areas; necessary facilities and utilities; required yards, open spaces, and recreational uses and facilities;

proposed landscaping, fencing, screening, and buffering and provision for trees protected or required by County regulations; proposed signs and lighting; and any other information that may be necessary or reasonably required. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Plan, Water Resource Management: A site-specific, comprehensive management plan prepared by a qualified environmental professional that details goals, actions, and BMPs (Best Management Practice) used by the development to minimize any adverse environmental impacts. The plan shall include but not be limited to the following components: Water Resource Management, including sources, uses, conservation, and water quality protection; Stormwater Management; Wastewater Treatment and Waste Management; Solid and Hazardous Waste Management; Chemical Waste Management (pesticides, oil, diesel, grease, etc.) and spills protocols; Integrated Pest Management; Fertilizer Management; Soils Management; Irrigation Resources and Systems Management; and Groundwater Management. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Pollution-Control Credit: An estimate of the average annual load reduction achieved by a practice that can be counted towards the overall average load reduction achieved by the stormwater management system.

Pollution-Control Measures: Temporary or permanent management strategies that are applied to protect air and water quality by preventing or minimizing the pollution of the air, surface water, and groundwater. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Predevelopment: Conditions that exist on a site at the time of permit application. Unauthorized site preparation activities will not be considered as predevelopment conditions.

Preservation or Preserve: To set aside in perpetuity areas of native habitat that must not be disturbed in accordance with the Principles for Evaluating Development Proposals in Native Habitats in the Environment Chapter of the Comprehensive Plan. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Preservation or Preserve Trees: Those trees to be preserved as specified in a County Tree Removal and Protection permit under Chapter 54, Article XVIII. Tree Protection. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Pretreatment: Stormwater volume and/or water quality controls applied upstream from or before capture, storage, treatment, infiltration, and/or harvesting by a subsequent stormwater management practice in a treatment train.

Rain Barrel is a rainwater storage vessel that captures runoff from a roof with a capacity less than or equal to 80 gallons. Systems using rain barrels for storage, including systems that link several barrels together in series, do not constitute an acceptable BMP for the Environmental Resource Permit program administered by the Southwest Florida Water Management District.

Rainwater is runoff from a roof which is collected before it contacts the ground.

Reclaimed Water: Water that has received at least secondary treatment and which is reused after flowing out of a wastewater treatment facility. (Rule 62-600.200, Florida Administrative Code)

Redevelopment: The construction, installation, replacement, reconstruction, alteration, or other material change of a structure, impervious surface, drainage facility, or part thereof on a previously developed site requiring a development order or permit. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Retention: The prevention of direct discharge of storm runoff into receiving waters; included as examples are systems which discharge through percolation, exfiltration, and evaporation processes and which generally have residence times less than 3 days. (SWFWMD 40d-Basis of Review)

Seasonal High Water Table (SHWT): The elevation to which the ground and surface water can be expected to rise due to a normal wet season.

Soils: Defined in the current United States Department of Agriculture Soil Survey of Sarasota County, Florida. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Stormwater Harvesting: Captured stormwater that is not allowed to discharge into a stormwater system or a natural conveyance system but is instead used for an activity such as irrigation.

Stormwater Harvesting Rate: The rate at which stormwater is harvested, which is typically expressed in inches per day.

Stormwater Harvesting System: Combination of a specified harvesting volume and rate of use intended to achieve a yearly average reduction in discharge mass; typically including a surface detention pond or other methods of storage.

Stormwater Management System: The appurtenances, facilities, and designed features of the property, which collect, convey, channel, hold, treat, detain, or divert, or otherwise manage stormwater runoff. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Stormwater Utility: A means of "funding of a stormwater management program by assessing the cost of the program to the beneficiaries based on their relative contribution to its need. It is operated as a typical utility which bills services regularly, similar to water and wastewater services." (FLA. STAT. § 403.031(17) (2008))

Survey: A survey as defined in the Minimum Technical Standards for Surveying, Chapter 61617, Florida Administrative Code. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Treatment Train: An integrated series of stormwater management practices, each of which provides incremental stormwater attenuation and/or treatment benefits.

Turf: A piece of grass-covered soil held together by the roots of the grass. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 54, ART XXXII, § 54-1023)

Waterbody: A natural body of water including rivers, lakes, streams, springs, ponds, and all other natural bodies of water including tidal, fresh, brackish, and saline. (SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Water Quality: A desired standard or degree of excellence defined by the physical, chemical, biological, and aesthetic characteristics of water in an attempt to preserve or attain its purest state of having no contaminants. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Water Quality Degradation: The natural and/or anthropogenic introduction of sediments and/or contaminants into ground or surface water that would result in a violation of State Water Quality Standards or that would prevent those waters from meeting designated present and future most beneficial uses. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Water Quality Monitoring Program: A comprehensive sampling program designed to assess the surface water quality of a specific body or bodies of water that includes, but is not limited to, the following components: Physical and chemical parameters; analytical methods; standard operating procedures (SOPs); sampling locations; frequency and duration of sampling; and data analysis and reporting. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

Water Quality Standards: 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 anti-degradation policy, and the moderating provisions contained in Chapter 62-4, F.A.C., adopted pursuant to Chapter 403, F.S. for surface water and Rule 62-520-400, F.A.C. for groundwater. (**DRAFT** SARASOTA COUNTY CODE OF ORDINANCES, CH. 74, ART I, § 74-7)

1.7 REFERENCES

1. Florida Department of Environmental Protection. 2006a. Water Resource Implementation Rule, Chapter 62-40, Florida Administrative Code. May 7 2006.

2. Florida Department of Environmental Protection. 2006b. Integrated Water Quality Assessment for Florida: *2006 305(b) Report and 303(d) List Update*. May 2 2006.
3. Florida Department of Environmental Protection. Environmental Resource Permitting and Sovereign Submerged Lands Rules. Accessed July 12 2008 at: http://www.dep.state.fl.us/water/wetlands/erp/rules/stormwater.index.htm.
4. Harper, H. H. and D. M. Baker. Evaluation of Current Stormwater Design Criteria within the State of Florida: Final Report. Prepared for Florida Department of Environmental Protection. June 2007.
5. Jones Edmunds & Associates, Inc. Sarasota County County-Wide Non-Point Source Pollutant Loading Model. August 2005.

1.8 APPENDICES

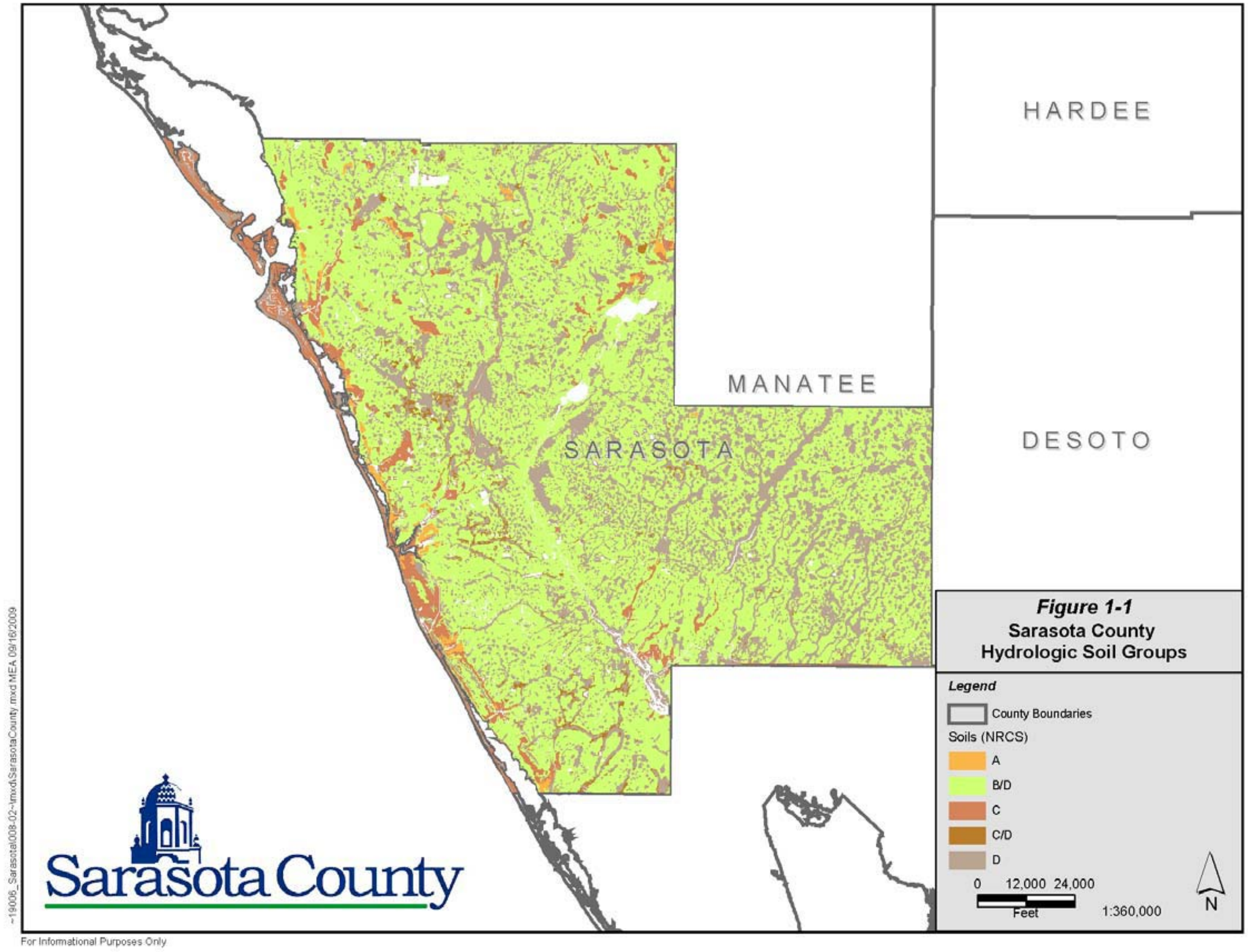

Figure 1-1 Hydrologic Soil Groups

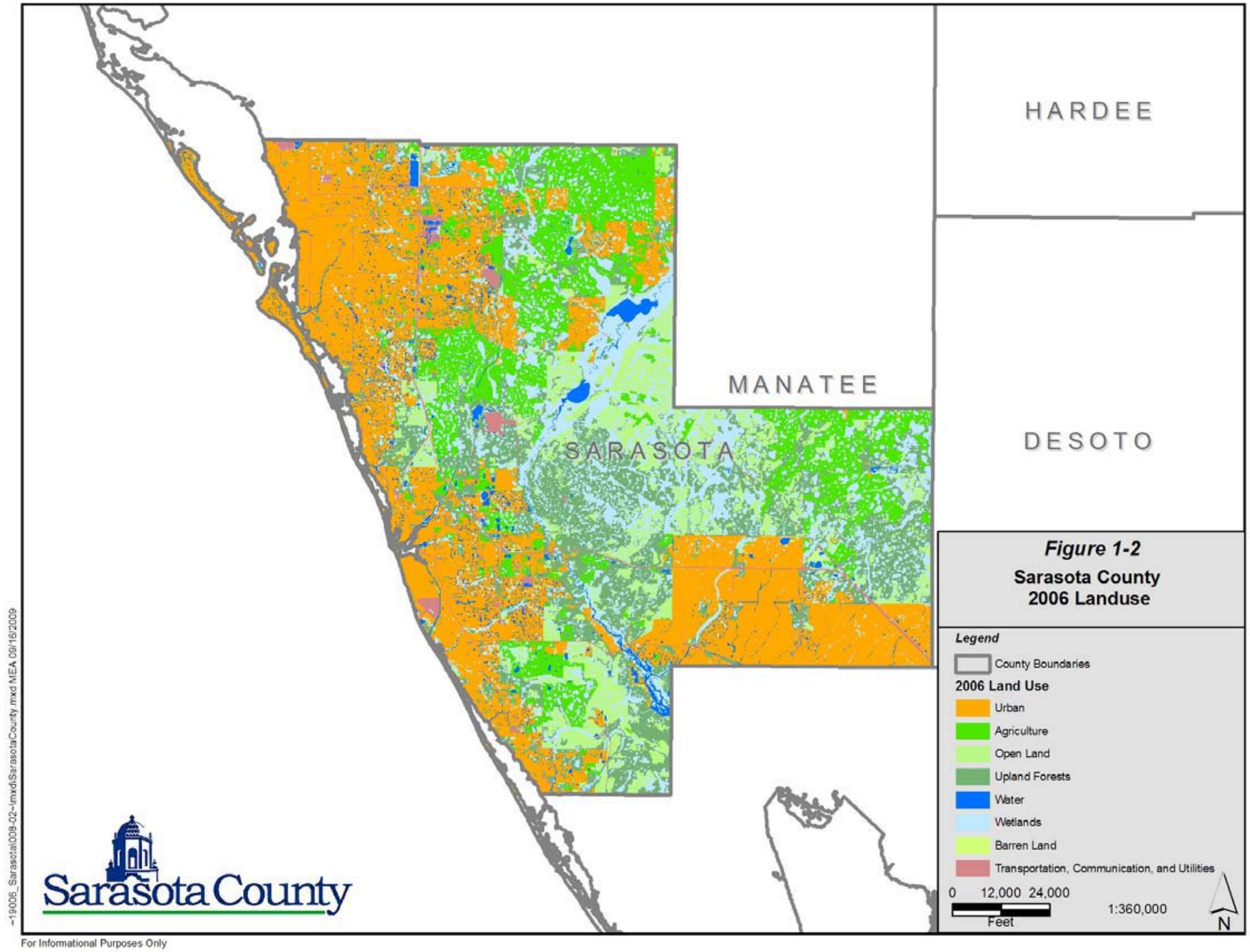

Figure 1-2 2006 Land Use

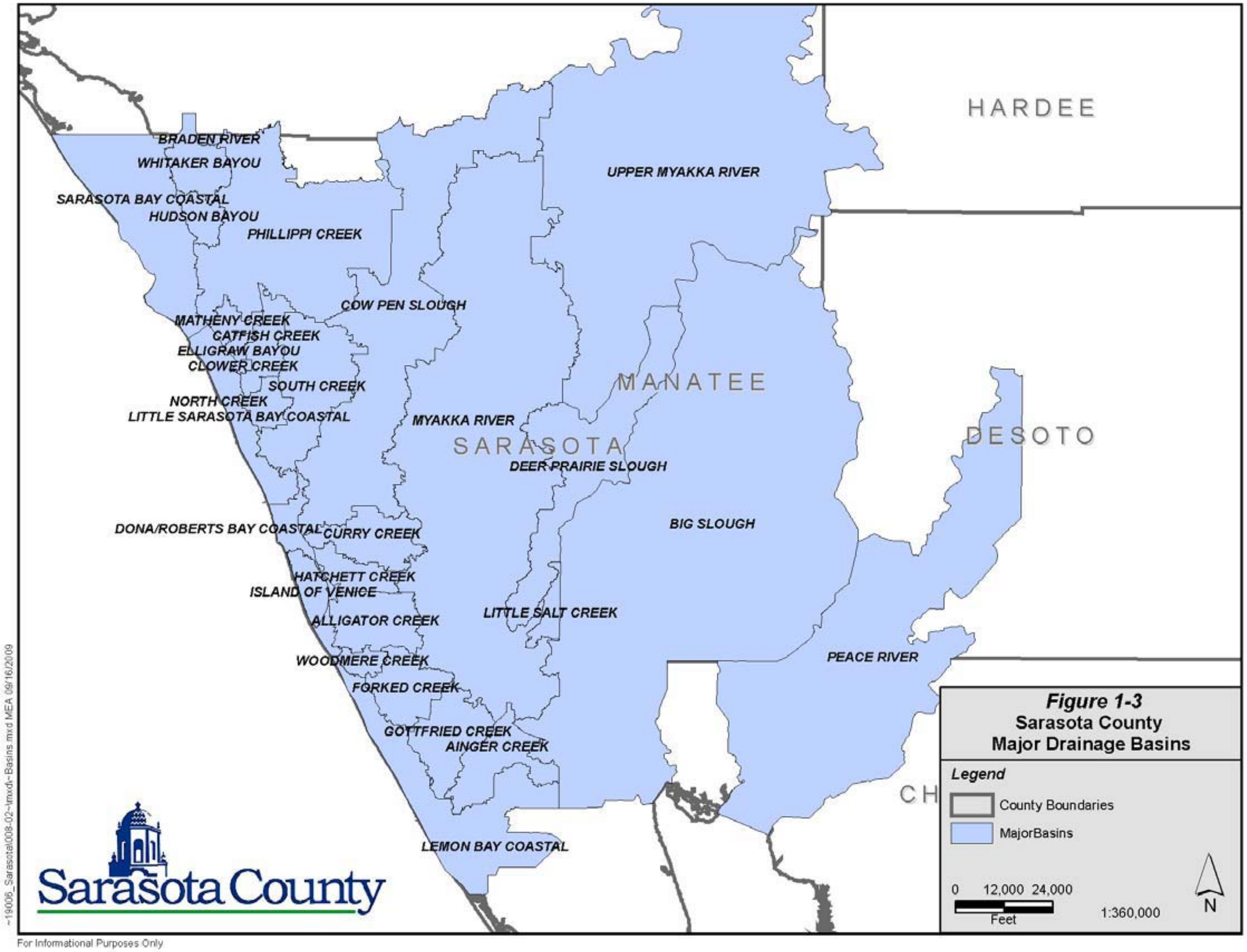

Figure 1-3 Major Drainage Basins

CHAPTER 2: Evaluating Your Site and Planning for LID

2.0 OVERVIEW

To achieve optimal performance of LID systems, project planners and engineers must adopt a comprehensive and iterative approach to site evaluation, planning and design, and monitoring and feedback. This chapter provides guidance on the *process* of assessing a site and planning for LID so that opportunities to protect water resources are maximized and adverse development impacts are minimized.

Site choice is the first decision affecting the success of LID applications to any project. When the project location is not predetermined, planners are encouraged to consider compatibility with LID principles and practices in their site selection, an approach that complements and/or satisfies Sarasota County's development standards and stormwater management requirements.

The County's *Land Development Regulations*, Article I Sec. 74-4, require development projects to provide "adequate stormwater management [so as] to reduce the impact of flooding to a minimum" and "protection of Sarasota County's natural systems and scenic resources, including the quality of air and both surface and groundwaters and the preservation of their ecological integrity." Given that LID principles aim to reduce total and peak volumes of stormwater runoff, thereby reducing pollutant loading to receiving waters, applying them to a development project—from site selection to long-term operations and maintenance—can help ensure that these County land-development standards are achieved.

Rather than focusing solely on treating stormwater runoff once it has been generated from a site, LID relies primarily on source controls and spatially distributed practices and systems that complement centralized, structured stormwater controls. Preserving the hydrologic signature of a site to promote management of stormwater runoff volumes and quality *at the source,* integrated with a *series* of on-site treatment practices, reduces the demand on centralized stormwater treatment systems. This is typically referred to as a "treatment train" approach to stormwater management. While conventional stormwater design typically involves constructing a single retention or detention pond to meet volume storage and pollutant-control requirements for each basin, treatment-train design involves constructing multiple practices in series, where each individual practice provides incremental benefits that collectively achieve storage and pollution-control requirements. Project planners and engineers are encouraged to evaluate and design sites with a holistic perspective and in a fashion that is consistent with the treatment-train approach.

Fundamental LID principles such as those listed below should be considered in the development planning and design process:

1. Preserve or conserve site features and assets that facilitate natural hydrologic function.

2. Minimize generation of runoff from impervious surfaces (i.e., use peak and total volume controls).
3. Minimize runoff contamination (i.e., use load controls) as close to the source as possible.
4. Promote distributed retention, detention, treatment, and infiltration of runoff.
5. Capture and harvest stormwater on site.
6. Minimize site disturbance and compaction of soils through low-impact clearing, grading, and construction measures.

In its overview of the site-assessment and planning processes, this chapter provides examples of specific LID practices supporting these principles. This chapter does not; however, address the average annual load reduction or the flood control that can be achieved by implementing such practices. Design standards and methods for calculating the effectiveness of certain practices are provided in Chapter 3. Applicants should discuss any practices not described in Chapter 3 with Sarasota County staff and SWFWMD staff at the pre-application meetings if they wish to include these as a part of their permitted stormwater treatment system.

2.1 SITE ASSESSMENT

In most development projects, stormwater systems are designed to attenuate and treat altered hydrologic conditions that result from implementing a master development plan. Plans for new development typically require the following:

- Clearing onsite vegetation.
- Disturbing and compacting native or parent soils.
- Importing and grading fill material to establish the construction base and drainage contours.
- Constructing infrastructure to facilitate drainage away from the site.
- Introducing new landscapes that require nutrient and water inputs greater than natural conditions to thrive.

Rather than fitting the stormwater system into the predetermined site plan, LID encourages an alternative design approach that integrates existing site features that facilitate natural hydrologic functions into the master plan. LID systems are designed to use and enhance predevelopment hydrologic, soil, and landscape conditions that promote on-site interception, capture, storage, treatment, and infiltration of stormwater. Site assessment, the first step in implementing this type of LID approach to stormwater management, involves careful consideration of the project's intent and thorough evaluation, documentation, and analysis of predevelopment site conditions.

2.1.1 Defining Project Intent

The type of development being planned, the expected uses, and the anticipated users of a site all have implications for effectively integrating LID features into the site, so these factors should be identified and documented early in any project. The applicant should consider the following questions regarding the project's fundamental intent:

1. Is the project new or greenfield development, redevelopment or infill, or retrofit of an existing site?
2. Is the property planned (and zoned) for residential, commercial, industrial, or public use?
3. What local standards and/or programs offer incentives for and/or discourage implementation of certain LID practices?
4. Who are the anticipated users of the site (primary and secondary) and what are the project planners' expectations of how they will use the site?

An approach that includes LID is compatible with all types of development; however, the suite of LID practices most appropriate for the project can vary significantly from one site to the next depending on the answers to the questions above. The list of practices that can be applied to new development of a relatively undisturbed site is usually extensive, ranging from opportunities to preserve tree canopy and natural depressions in the landscape to flexibility in sizing and location of stormwater ponds to allow for efficient capture and harvesting of stormwater. Potential practices appropriate for retrofit applications, on the other hand, might be limited in number because of existing site constraints yet can be extensive in terms of the potential design scenarios for practices that are appropriate. Zoning requirements for different land-use categories may support the construction of certain LID practices and limit or prohibit others.

Those who will be using the site and the manner in which they will be using it also can influence the appropriateness and effectiveness of LID systems. Stormwater systems in residential applications, for example, are typically exposed and can often be accessed physically by homeowners, so it is important that LID applications not only function as stormwater quantity and quality measures, but also that they are perceived as functional community amenities rather than nuisances or hazards.

2.1.2 Evaluating Predevelopment Conditions

When evaluating a site for the feasibility of integrating LID practices, the project planner and/or engineer must conduct a thorough analysis of predevelopment conditions. For this manual, predevelopment conditions are site features – including both assets and constraints –as they currently exist on the site. For new development projects, this predevelopment might closely resemble a natural or native landscape, whereas for redevelopment it is likely to be altered significantly from natural or native conditions. In this phase of the project, the planner or design engineer should identify, understand, and document site conditions that facilitate rainfall interception, capture, storage, evaporation, transpiration, infiltration, treatment, and harvesting. It is also important to note site features that restrict these natural hydrologic processes and to consider options for mitigating degraded conditions.

One way to begin this evaluation is to conceptually trace the path of rainfall as it moves within and through the site, considering, for example, the following types of questions:

- What natural features (tree canopy, vegetation, etc.) intercept and/or capture rain as it falls on the site and return portions of it to the atmosphere via evaporation and/or transpiration?
- What is the topography of the site and does it promote stormwater drainage away from the site or capture and infiltrate stormwater on site?
- What are the hydrologic soil groups (as classified by the most current NRCS Soil Survey for Sarasota County available at: http://websoilsurvey.nrcs.usda.gov/app/) and distributions on site, and to what extent do they promote infiltration of rainfall (i.e., what are their infiltration rates)? As noted in Chapter 1, most soils in Sarasota County are classified in the B/D hydrologic soil group (moderately well-drained when dry, not well-drained when wet) due to a shallow SHWT.
- Where and to what extent have soils been disturbed and/or compacted, reducing infiltration rates and promoting runoff generation?
- What is the elevation of the seasonal high water table throughout the site?
- Do critical and sensitive areas (wetlands, riparian areas, etc.) that provide capture, uptake, and filtering of pollutants exist on site and have they been protected or disturbed?
- What physical structures (buildings, parking lots, etc.) intercept rainfall and convey it as stormwater to other areas of the site and/or away from the site?
- What pervious surfaces (natural and structural) allow stormwater to infiltrate to parent soils?
- What impervious surfaces (natural and structural) prevent infiltration of stormwater and promote runoff?
- What engineered stormwater treatment systems exist on site and could they be enhanced or retrofitted to improve performance?

The collective opportunities and constraints posed by predevelopment site conditions will directly influence the final suite of LID practices most appropriate for a site.

Planners and design engineers should assemble any available data and analyses that improve their understanding of predevelopment conditions and hire the appropriate Florida-registered and -licensed professionals to conduct additional surveys and/or inventories to fill important information gaps. Recommended data sets and analyses to gather for the site and surrounding areas include but are not limited to the following:

- Historical and current land-use maps
- Aerial photographs
- Road and utility surveys
- Topographic and drainage maps
- Floodplain and wetland maps
- Riparian zone/stream buffer maps
- Most current NRCS Soil Survey data for Sarasota County, (available at: http://websoilsurvey.nrcs.usda.gov/app/) , or other historical soil information
- Tree and vegetation surveys
- Rainfall data
- Hydrologic analyses

With these, data planners and design engineers can identify key site opportunities and constraints to LID, including those that affect the ability of the LID systems to control stormwater quantity and quality at the source, infiltrate stormwater on site, function effectively as a treatment train, and capture and store stormwater for harvesting.

2.2 SITE PLANNING AND DESIGN

Site planning for LID stormwater management is similar to planning for conventional stormwater management in that it applies structural engineered designs to meet stormwater quantity and quality criteria. LID site planning differs; however, in that it extends well beyond structural stormwater controls to include guidance on the fundamental design of a development; methods for protecting water quality and minimizing runoff generation at the source; practices that use physical, biological, and geochemical processes for stormwater treatment; and innovative stormwater harvesting options. Most if not all LID practices provide multiple stormwater, environmental, and aesthetic benefits, but it is useful to consider the entire suite of practices that might be applied in terms of their relationship to the six fundamental LID principles discussed in this manual:

1. Preserve existing site assets.
2. Minimize and control runoff generation at the source.
3. Promote infiltration.
4. Promote stormwater harvesting.
5. Minimize site disturbance.
6. Preserve onsite seasonal high water table

2.2.1 Preserving Site Assets

Planning for projects that include LID requires design that capitalizes on the beneficial features, or assets, of a site. A thorough inventory and composite analysis of site features helps the project planner identify design options for conserving, preserving, protecting, and enhancing areas that promote LID function. These beneficial features include the following:

- Tree canopy and “Grand Trees.”
- Native species of vegetation.
- Natural landscape depressions distributed throughout the site.
- Native soils that have not been compacted or disturbed.
- Stream buffers or riparian zones.

Careful management of these assets not only protects critical water resources, but can also reduce or eliminate certain costs of site development, including those for clearing vegetation, site grading, and erosion control as well as post-development maintenance costs.

2.2.2 Minimizing and Controlling Runoff Generation at the Source

Conventional development practices modify natural site drainage pathways by introducing a network of impervious surfaces (rooftops, driveways, sidewalks, roads, and gutters) that route stormwater away from the site or to stormwater treatment basins. While this process is very efficient at controlling runoff, it alters the hydrologic signature of the site significantly, increasing volumes and rates of runoff while conveying pollutants away from the site. Alternatively, LID emphasizes minimizing and controlling runoff and pollutant generation at the source. LID facilitates onsite infiltration by applying practices that preserve pervious surfaces, limit the total area of impervious surfaces introduced, and disconnect impervious surfaces.

Source-control design strategies, whether applied to new residential, commercial, or industrial development, are valuable not only for achieving stormwater quantity and quality targets, but also for reducing site preparation and infrastructure costs. Among the key LID site-design practices that promote volume control and water quality protection at the source (subject to zoning code requirements or restrictions) are the following:

- Preserving mature tree canopy, “Grand Trees,” and understory vegetation.
- Clustering homes, buildings, and other structures on smaller lots.
- Constructing greenroof stormwater treatment systems (Section 3.4).
- Minimizing impervious areas.
- Minimizing directly connected impervious areas (DCIA).
- Using shared driveways in residential applications.
- Using narrower roads with a pervious shoulder and/or right of way.
- Using road layout that minimizes linear impervious area.
- Using alternative parking lot design that minimizes total impervious area.
- Designing landscapes that minimize turf or landscape plants with high nutrient and water requirements.

- Designing landscapes that maximize preservation of existing native vegetation and introduce new vegetation that is appropriate for site conditions (e.g., Florida-friendly landscaping).
- Irrigating for establishment only or use of smart water-application technologies, such as soil moisture sensors, that maximize irrigation efficiency.

2.2.3 Promoting Infiltration

Many LID strategies that reduce generation of stormwater at the source do so by preserving and promoting opportunities for infiltration on site. While potential stormwater infiltration capacity and rates are constrained by predevelopment conditions such as SHWT and soil types, infiltration-dependent LID practices can be designed to perform effectively as part of a treatment train under most site conditions in Sarasota County. Optimal areas for locating infiltration-dependent stormwater practices (i.e., those with the highest infiltration rates) should be identified during the site-assessment phase of development. Specific LID practices that preserve or enhance infiltration function throughout the catchment basin include the following:

- Retaining pervious surface areas.
- Using bioretention applications.
- Using pervious pavements (Section 3.2) for parking lots and residential parking areas, driveways, walking and bike paths, sidewalks, and emergency vehicle access lanes.
- Engineering or amending soils to improve infiltration properties.
- Ecologically and biologically enhancing stormwater treatment ponds.

2.2.4 Promoting Stormwater and Rainwater Harvesting

Project planners and design engineers should consider stormwater itself as an asset that can be used to reduce the impact of development projects on Sarasota County water resources. Rather than designing systems that allow stormwater to leave the site, often exacerbating downstream flooding and surface water degradation, LID promotes treatment and harvesting of stormwater onsite. Stormwater harvesting can offset potable water demands significantly, particularly when used for outdoor irrigation, which accounts for approximately 50% of residential households' (Purdum, 2002) water use in Florida. Specific stormwater harvesting practices, such as the following, should be considered in site planning:

- Cisterns or rain barrels for collecting, storing, and using rainwater, air conditioning condensate, graywater for irrigating lawns and landscape beds, irrigating green roofs, washing vehicles, cooling tower make-up water, and toilet flushing as approved by Sarasota County health codes etc.

- Stormwater harvesting ponds, typically used for irrigating lawns and landscape beds (Section 3.3).
- Distribution pipes for non-potable water (i.e. stormwater harvesting or reclaimed water).

2.2.5 Minimizing Site Disturbance

Mechanisms to reduce site disturbance before, during, and after construction are some of the most critical elements of an integrated and effective approach to LID stormwater planning. Opportunities to preserve and promote natural hydrologic functioning of a site are often lost as a result of conventional development practices such as non-selective site clearing, export of native soils, importing of fill, mass grading, and construction in sensitive areas using heavy machinery. Compacting soils reduces the pore space available for storage and infiltration of stormwater. Some 80% of compaction occurs in the first pass of a vehicle across the soil, and compaction occurs to deeper depths in wetter soils. Clearing, grading, and construction measures that minimize site disturbance and promote LID function include:

- Minimizing the clearing area.
- Clearing selectively.
- Using smaller and lighter construction equipment where possible.
- Keeping heavy equipment outside of the drip line of preserved trees.
- Minimizing grading and importing of fill (e.g., through use of stemwall construction).
- Keeping heavy equipment off soils where infiltration-dependent stormwater practices will be used.
- Designating laydown areas for construction equipment and materials.

Sarasota County stormwater regulations provide maximum allowable compaction values when constructing certain LID practices, such as pervious pavements (see Section 3.2).

2.3 PERFORMANCE MONITORING AND FEEDBACK MECHANISMS

Applicants should provide a plan for performance monitoring and feedback mechanisms to ensure that LID systems are operating as designed or, alternatively, to alert stormwater managers when either individual practices or the entire systems are not achieving performance goals. This plan should allow monitoring and feedback to occur through all project phases: before, during, and after construction. Specific monitoring and feedback requirements are defined for each practice in Chapter 3 of this manual; however, these requirements should be confirmed with Sarasota County and SWFWMD staff during the pre-application meetings. It should be noted that the performance requirements and recertification requirements for stormwater systems may differ between Sarasota County and SWFWMD.

2.4 PROJECT GUIDANCE

In order to achieve a "best fit LID practice" for each site, a qualitative LID Guidance Tool has been provided for applicants that follow a "consumers guide" approach to understanding the benefits or challenges of each LID practice in this manual. With this tool, the applicant can streamline the planning approach and focus on only those LID practices which are practical for application at each site according to three major categories: Refer to Figures 2-1 and 2-2.

THE LID GUIDE FOR PLANNING PROJECTS

A. General Site Considerations: *What is the nature of the project?*

B. Environmental Site Considerations: *What natural features may provide opportunities or influence LID performance?*

C. Special Watershed Site Considerations: *Are there any special stormwater management issues that may need addressing with LID practices?*

LOW IMPACT DEVELOPMENT PLANNING CONSIDERATIONS	PROJECT APPLICABILITY (Y or N)	LOW IMPACT DEVELOPMENT ALTERNATIVES AVAILABLE TO MEET STORMWATER MANAGEMENT SITE NEEDS IN SARASOTA COUNTY							
		DETENTION WITH BIOFILTRATION (SEE SECTION 3.1)	PERVIOUS PAVEMENTS (SEE SECTION 3.2)	STORMWATER HARVESTING (SEE SECTION 3.3)	GREENROOF TREATMENT (SEE CHAPTER 3.4)	RAINWATER HARVESTING (CHAPTER 3.5)	SHALLOW BIORETENTION (CHAPTER 3.6)	VEGETATIVE FILTER STRIPS (CHAPTER 3.7)	CONFINED URBAN VEGETATIVE SYSTEMS (CHAPTER 3.8)
A. GENERAL SITE CONSIDERATIONS									
A.1-THE PROJECT IS PLANNED TO BE CONSTRUCTED ON UNDEVELOPED LAND WITH FLEXIBLE LOCATIONS FOR STORMWATER MANAGEMENT.		●	●	●	●	●	●	●	●
A.2-THE PROJECT IS A REDEVELOPMENT AREA OR RETROFIT PROJECT WHERE NO STORMWATER PONDS EXIST.		◑	●	○	●	●	◑	◑	●
A.3-THE PROJECT IS A PROPOSED LINEAR PROJECT (I.E. NEW ROADWAY).		●	●	○	○	○	●	●	◑
A.4-THE PROJECT IS COMPRISED OF A LARGE MIXED USE OR PLANNED DEVELOPMENT (RESIDENTIAL/COMMERCIAL DEVELOPMENT)		●	●	●	●	●	●	●	●
A.5-THE SITE IS PLANNED FOR A COMMERCIAL LARGE "BIG BOX". BUILDINGS AND LARGE PARKING AREAS.		●	●	●	●	◑	●	◑	●
A.6-THE PROJECT IS PLANNED AS A CLUSTERED, HIGH INTENSITY MULTI-FAMILY RESIDENTIAL OR "NEW URBANISM" PROJECT.		●	●	●	●	◑	●	◑	●
B. ENVIRONMENTAL SITE CONSIDERATIONS									
B.1-THE SEASONAL HIGH GROUNDWATER TABLE IS LESS THAN 1.5 FEET BELOW LAND SURFACE.		●	○	●	●	●	○	○	●
B.2-THE SOILS ON THE SITE ARE POORLY DRAINED WITH LESS THAN 2 INCHES/HR INFILTRATION (I.E. SCS TYPE B/D OR D).		●	◑	●	●	●	◑	◑	●
B.3-THE SITE LIES WITHIN THE 100 YEAR FLOODPLAIN.		●	◑	●	●	●	●	◑	●
B.4-THE PROJECT AREA INCLUDES SPECIAL HABITATS OF CONCERN OR REQUIRES SPECIAL PROTECTION MEASURES.		●	◑	●	●	●	●	●	●
B.5-THE PROJECT IMPACTS WETLANDS OR THERE ARE EXISTING IMPACTED WETLANDS THAT MAY BENEFIT FROM STORMWATER.		●	◑	●	◑	●	●	◑	◑
B.6-THE SITE REQUIRES FILL MATERIALS FOR DEVELOPMENT		●	●	●	◑	●	●	●	●
B.7-THERE ARE OPPORTUNITIES TO PRESERVE FORESTED AREAS FOR NON-PRESUMPTIVE STORMWATER TREATMENT BENEFITS.		●	●	●	●	●	●	●	●
B.8-THE PROJECT SITE HAS NO POSITIVE OUTFALL		◑	◑	●	●	●	◑	◑	◑
C. SPECIAL WATERSHED SITE CONSIDERATIONS									
C.1 THE PROJECT LIES WITHIN A WATERSHED OF SPECIAL CONCERN (I.E. WITHIN A PEAK SENSITIVE OR VOLUME SENSITIVE AREA).		◑	◑	◑	◑	◑	◑	◑	◑
C.2 THE WATERSHED RECEIVING STREAM IS AN OUTSTANDING FLORIDA WATER (OFW).		◑	◑	◑	◑	◑	◑	◑	◑
C.3 THE WATERSHED LIES WITHIN AN IMPAIRED WATER BODY AND MAY HAVE SPECIFIC TMDL'S INDENTIFIED FOR NUTRIENTS.		◑	◑	◑	◑	◑	◑	◑	◑

Figure 2-1 LID Site Planning and Evaluation Guidance Chart

LID SITE EVALUATION AND GUIDANCE LEGEND		
THE LID PRACTICE IS BOTH FEASIBLE AND PRACTICAL AND IS RECOMMENDED FOR CONSIDERATION		●
THE LID PRACTICE MAY BE FEASIBLE BUT MAY REQUIRE SPECIAL MEASURES FOR PRACTICAL IMPLEMENTATION		◑
THE LID PRACTICE POSES PRACTICAL CHALLENGES FOR IMPLEMENTATION THAT MAY LIMIT THE APPLICATION		○

NOTE: THE LID EVALUATION AND GUIDANCE TOOL IS PROVIDED TO AID STORMWATER PROFESSIONALS IN PLANNING FOR SUCCESSFUL LID PROJECTS. THE STORMWATER PROFESSIONAL IS ADVISED TO EVALUATE LID OPTIONS FOR EACH CATEGORY APPLICABLE FOR THE PROPOSED PROJECT AS SHOWN IN FIGURE 2.2 AND THEN FOLLOW DESIGN RECOMMENDATIONS IN THE RESPECTIVE LID CHAPTER 3 SECTIONS. IT IS THE SOLE RESPONSIBILITY OF THE STORMWATER PROFESSIONAL TO DESIGN THE PROJECT TO EFFECTIVELY MEET BOTH SARASOTA COUNTY AND SWFWMD PERMITTING REQUIREMENTS FOR STORMWATER MANAGEMENT.

Figure 2-2 LID Site Planning Guide Legend

2.5 REFERENCES

1. Purdum, E. D. (2002). *Florida Waters: A Water Resources Manual from Florida's Water Management Districts*. Available: http://www.sjrwmd.com/floridawaters/index.html (Accessed 05/29/2009).

CHAPTER 3: LID Practices in Sarasota County

SECTION 3.1: Shallow Bioretention

3.1 SHALLOW BIORETENTION

Key Considerations	**Practice Intent:** ▪ Retain, infiltrate, and treat stormwater close to source. **Design Criteria:** ▪ It is recommended for the drainage area to be 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible.Treatment area consists of grass filter, ponding area, organic/mulch layer, planting soil, nutrient-absorption layer, and vegetation. **Advantage/Benefits:** ▪ Applicable to small drainage areas. ▪ Applicable to high water table conditions. ▪ Good retrofit capability. ▪ Can be planned as an aesthetic feature. **Disadvantages/Limitations:** ▪ Requires landscaping. **Maintenance Requirements:** ▪ Inspect and repair/replace treatment area components. ▪ Remove trash, litter, and sediment. **Monitoring/Record Keeping:** ▪ Maintain record of fertilizer application. ▪ Conduct biennial infiltration tests. **Recovery:** ▪ Retention volume must be recovered within 72 hours.
Pollutant Removal Potential	**H** **Total Suspended Solids** **H** **Nutrients**—Total Phosphorus/Total Nitrogen **H/M** **Metals**—Cadmium, Copper, Lead, and Zinc **M** **Pathogens**—Coliform, Streptococci, E.Coli
Stormwater Management Suitability	☒ **Water Quality** ☒ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Yes **High-Density/Ultra-Urban:** Yes **Drainage Area:** It is recommended for the drainage area to be 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible. **Shallow Water Table:** Seasonal High Water Table should be greater than 0.5 feet below retention area. **Soils:** Planting soils must meet specified criteria; no restrictions on surrounding soils.
Other Considerations:	Use of native plants is highly recommended.

L—Low, **M**—Moderate, **H**—High

3.1.1 General

3.1.1.1 Overview and Intent

Bioretention areas are shallow depressions used as structural stormwater controls to capture, treat, and infiltrate stormwater runoff. Within the bioretention area, nutrient-adsorption media, soils, mulch, and planted vegetation facilitate treatment and remove pollutants from the runoff. Multiple bioretention areas are often distributed throughout a larger catchment, providing numerous treatment and water storage areas. Although any one treatment area may be small, the cumulative effect can be significant. This distributed approach also better mimics predevelopment hydrologic conditions by promoting stormwater infiltration, thereby reducing runoff and recharging groundwater.

3.1.1.2 Applicability

Water Quantity Control

Bioretention systems are designed primarily for addressing stormwater quality. Although bioretention systems will provide some attenuation of peak flows, they will most likely not provide sufficient storage capacity to meet Sarasota County and SWFWMD water quantity control criteria.

Water Quality Control

Bioretention systems can be more effective than conventional retention systems due to the increased interaction of stormwater runoff with soil, microbes, and vegetation enhancing biogeochemical processes and improving water quality. Treating stormwater by bioretention can be very effective due to the variety of chemical, physical, and biological removal mechanisms.

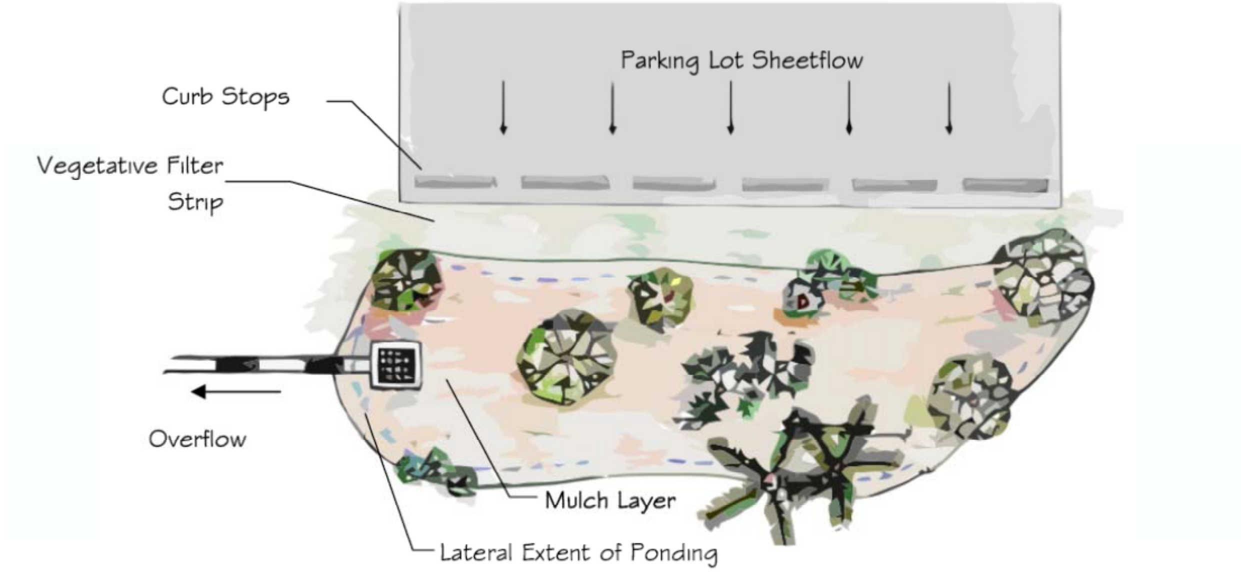

Figure 3.1-1 Plan View Illustrating a Shallow Bioretention System

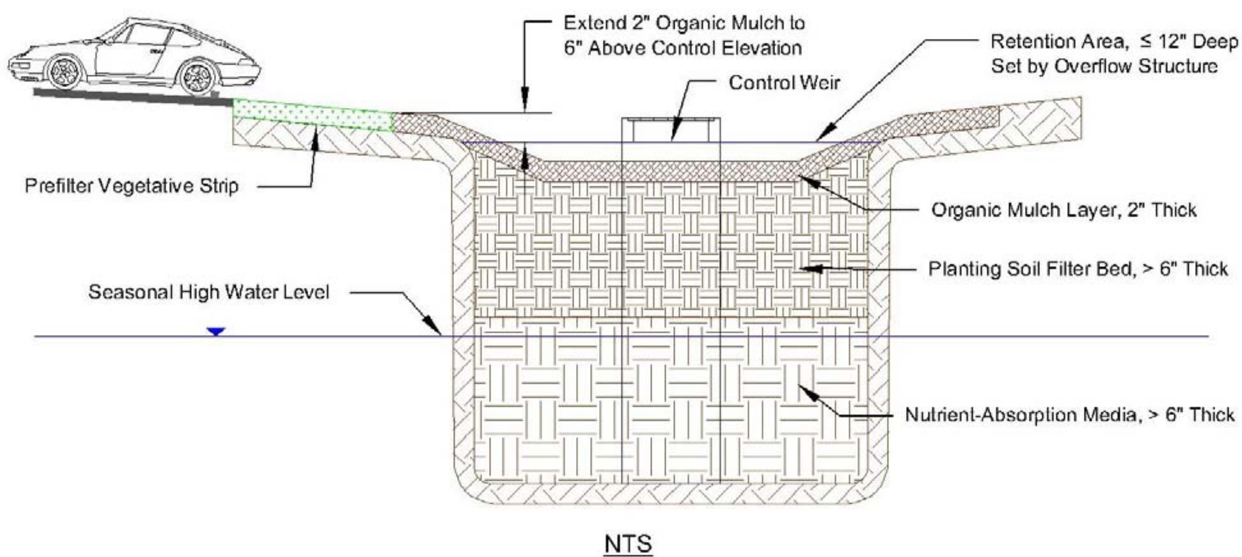

Figure 3.1-2 Cross Section View of a Shallow Bioretention System

General Feasibility

Bioretention systems are suitable for many types of development, from single-family residential to high-density commercial projects. Because the shape and sizing of systems are relatively flexible, the systems can be incorporated into many landscaped designs. These systems are an ideal structural stormwater control for use near impervious areas such as roadway medians, parking lot islands, and swales. Bioretention systems are also well suited for treating runoff from pervious areas, such as recreational fields or landscaped areas. Bioretention systems may also be used to treat roof runoff. Bioretention systems are not suitable for regional stormwater control.

Physical Constraints

When evaluating the appropriateness of a bioretention system, an applicant should consider some of the physical constraints associated with this type of treatment system, including:

A. Drainage Area – It is recommended for the drainage area to be 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible.

B. Seasonal High Water Table – Must be at least 0.5 foot below the bottom of the retention area.

C. Soils – Relatively high hydraulic conductivity in the surrounding soils.

3.1.2 Design Considerations and Requirements

The following criteria are to be considered **minimum** standards for the design of a shallow bioretention system in Sarasota County. Consult with SWFWMD to determine whether any variations must be made to these criteria or if additional standards must be followed.

3.1.2.1 General

A shallow bioretention must consist of the following (see Figures 3.1-1 and 3.1-2):

A. *Prefilter strip* – Where feasible, a prefilter or grass channel strip should be used between the contributing drainage area and the ponding area to capture course sediments and reduce sediment loading to the retention area. The applicant may provide other measures to minimize the sediments entering the system in lieu of a prefilter strip. Bioretention systems that do not include a prefilter strip or other measures will be subject to additional testing criteria.

B. *Retention area* – An area that provides temporary surface storage (less than 12 inches) for runoff before infiltration through the planting soil filter bed.

C. *Organic mulch layer* – A 2-3 inch layer that attenuates heavy metals, reduces weed establishment, regulates soil temperature and moisture, and adds organic matter to the soil.

D. *Planting soil filter bed* – A layer that provides at least 6 inches of planting media for vegetation within the basin as well as a sorption site for pollutants and a matrix for soil microbes.

E. *Nutrient-adsorption media* – A 6-inch layer at the bottom of the bioretention system that facilitates pollutant removal through sorption and denitrification.

F. *Woody and herbaceous plants* – Florida-friendly plants that provide a carbon source for the bioretention system, help facilitate microbial activity, and improve infiltration rates.

G. *Energy-dissipation mechanism* – A structure that reduces runoff velocities, distributes flow, and reduces disturbance of the mulch layer.

H. *Overflow pipe or spillway* – A structure to allow rainfall events that exceed cell volume capacity to bypass the system. The discharge invert should be set no higher than 12 inches above the soil surface with the applicable downstream erosion-control measures.

3.1.2.2 Location and Planning

Bioretention systems are designed for intermittent flow and should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

Locations of bioretention systems should be integrated into the site-planning process, and aesthetic considerations should be taken into account in their siting and design. All control elevations must be specified to ensure that runoff entering the facility does not exceed the design depth.

3.1.2.3 Sizing Requirements

Prefilter Strip

A. The prefilter strip design will depend on topography, flow velocities, volume entering the buffer, and site constraints.

B. The prefilter strip is typically a vegetated or grassed channel.

C. Flow rates entering the bioretention system must be less than 1 foot per second to minimize erosion.

Ponding Area

A. The maximum ponding depth must be less than 12 inches below the overflow structure.

B. The recovery time must be less than 72 hours under seasonal high water table conditions.

Organic Mulch Layer

A. The surface organic mulch layer must be 2-3 inches deep and cover the surface of the basin to above the expected high water line.

B. Mulch depth must never exceed 4 inches or soil aeration may be reduced.

C. Hardwood mulch must be used due to its higher pH, improved microbial activity, and slower decomposition rate. Examples of acceptable mulches are those made from melaleuca or eucalyptus trees. Pine bark or pine straw is not acceptable.

D. Partially composted mulch is acceptable, especially in the lower parts of the depression as this will reduce the tendency of the mulch to float.

Planting Soil Filter Bed

A. The planting soil filter bed must be at least 6 inches thick.

B. The bed material should be sandy loam, loamy sand, or loam texture.

C. Clay content should be between 3 and 5%.

D. Soil pH should be between 5.5 and 6.5.

E. Soil organic matter content must be between 3% and 10% by volume. Soil amendments to raise the organic matter content should have a carbon-to-nitrogen ratio of at least 50%.

F. The soil mix must be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches in size.

Nutrient-Adsorption Layer

A. The nutrient-adsorption layer must be at least 6 inches thick.

B. The unit weight should be more than 80 pounds per cubic foot when dry.

C. Greater than 15% but less than 30% of the particles passing the #200 sieve.

D. The media should be more than 50% uniformly graded sand by volume and the sand must not contain shale.

E. The media water holding capacity should be at least 35% as measured by porosity.

F. At the specified unit weight noted above the vertical permeability must be at least 0.03 inch per hour but less than 0.25 inch per hour.

G. The media must have an organic content of at least 5% by volume. The organic content must be in the form of 1-inch hardwood chips (e.g., melaleuca or eucalyptus woodchips) evenly distributed throughout the layer.

H. The media pH should be between 6.5 and 8.0.

I. The concentration of soluble salts should be less than 3.5 g (KCL)/L.

J. The sorption capacity of the sand should exceed 0.005 mg OP/mg media.

K. The residual moisture content should exceed 50% of the porosity.

3.1.2.4 Discharge Requirements

The bioretention system is primarily a water quality treatment system and does not need to meet any specific discharge requirements. However, an overflow structure and non-erosive overflow channel must be provided to safely pass flows that exceed the storage capacity of the bioretention system to a stabilized downstream area or watercourse. The complete stormwater treatment system for the site must meet SWFWMD and Sarasota County water quantity discharge requirements.

3.1.2.5 Recovery Requirements

The retention volume used to estimate the average annual load reduction must be recovered in less than 72 hours under SHWT conditions.

An appropriate Florida-registered and -licensed professional shall perform a recovery analysis using site-specific geotechnical data to determine storage recovery. For guidance on the number of borings refer to SJ93-SP10 (SJRWMD 1993).

The assumed hydraulic conductivity for the planting soil must be stated clearly as this will be used when testing bioretention systems.

3.1.2.6 Water Quantity Credits

Bioretention systems are typically used for water quality treatment and not for flow attenuation. However, the effectiveness of a bioretention system at attenuating peak flows can be calculated using one of the following procedures:

A. Calculating the Curve Number (CN) for the bioretention area and including this in the area weighted CN for the entire site.

B. Explicitly modeling the hydraulic functioning of the bioretention system and its overflow control structure.

3.1.2.7 Water Quality Treatment Requirements/Credits

No specific treatment requirement is associated with a single bioretention system. These systems are intended to be part of a treatment train, where each practice in the train provides incremental water quality benefits. The level of treatment that can be expected from these systems is based on the average annual volume of water captured and infiltrated by the bioretention system. The percentage of the average annual runoff volume that is infiltrated by the bioretention system must be estimated using one of the following methods:

A. *Continuous simulation* – A continuous simulation of the bioretention system using an applicable long-term rainfall record (at least 20 years).

B. *Design Curve* - Figure 3.1-3 may be used to determine the percentage of the average annual volume of water infiltrated or retained by the bioretention system. This figure requires that the equivalent impervious area (EIA) and retention volume are known. The EIA is equal to the mean annual runoff coefficient (Table A-1) multiplied by the drainage area. It should be noted that when using Table A-1 a directly connected impervious area should be treated as 100% DCIA rather than having a CN of 98.

The average annual pollutant load reduction is assumed to be equivalent to average annual percentage of runoff that is retained and infiltrated by the bioretention system.

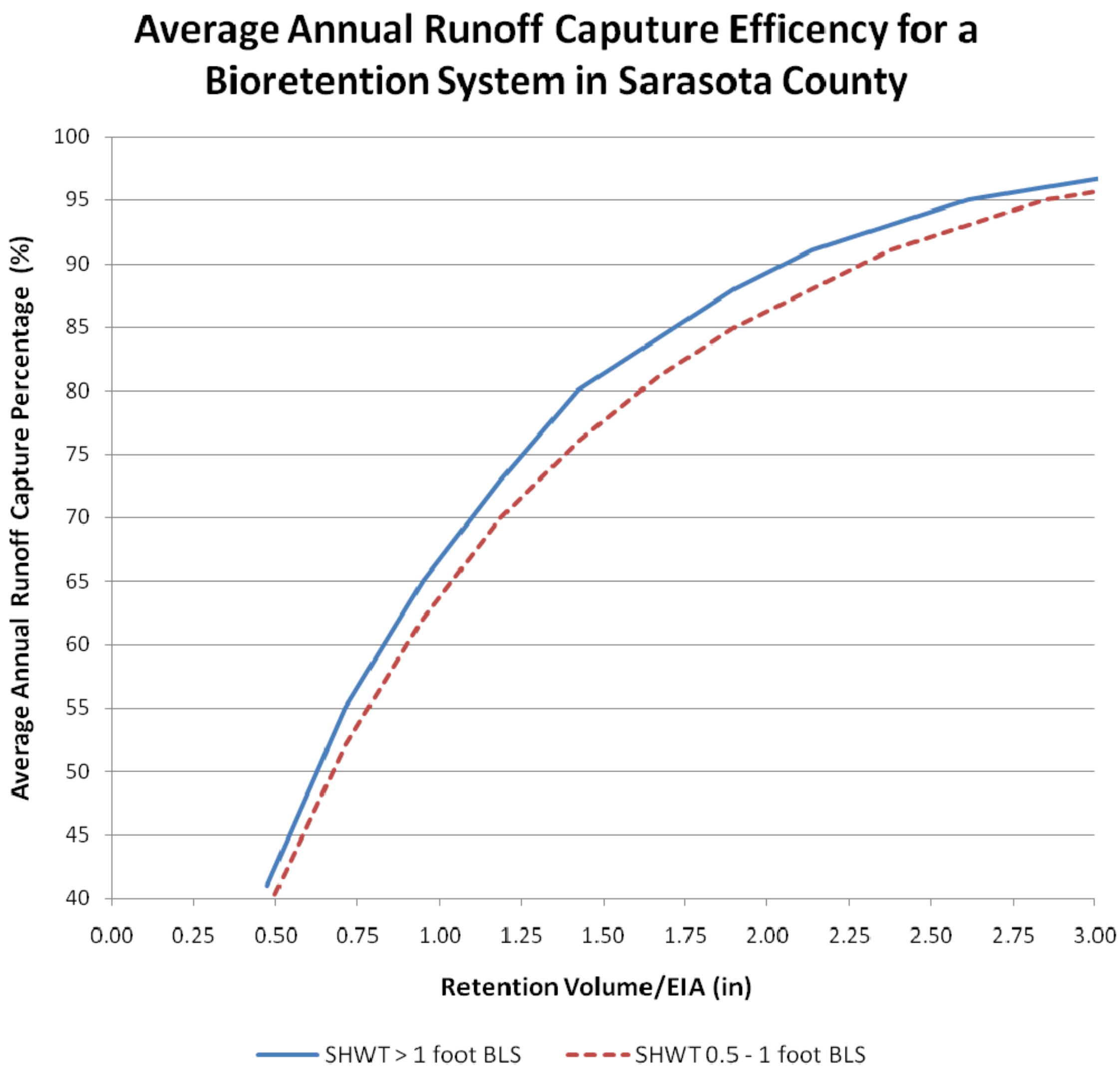

Figure 3.1-3 Average Annual Runoff Capture Efficiency for a Bioretention System in Sarasota County

Where: EIA is the Equivalent Impervious Area for the contributing area and the Storage Volume is the surface retention volume of the bioretention system.

3.1.2.8 Maintenance Access

Access to the bioretention area must be provided at all times for inspection, maintenance, and landscaping upkeep. There must be sufficient space around the bioretention system to allow accumulated surface sediments to be removed should the system should fail infiltration tests or inspection.

3.1.2.9 Safety Features

Shallow bioretention systems generally do not require any special safety features. Fencing these facilities is not generally desirable. Railings or a grate can be used to address safety concerns if the area is designed with vertical walls.

3.1.2.10 Landscaping

Landscaping enhances the performance and function of bioretention systems. Selecting plant material based on hydrologic conditions in the basin and aesthetics will improve plant survival, public acceptance, and overall treatment efficiency. Native or Florida-friendly plants should be selected. All landscaping recommendations should be considered before storm flows are conveyed to the bioretention system:

Landscaping of Catchment

A. The unpaved contributing area should be well vegetated to minimize erosion and sediment inputs to the bioretention system.

B. Where feasible a prefilter vegetative strip or vegetative swale should be installed.

C. If used, trees must be spaced 12 to 15 feet apart depending on the type.

D. Plants must be placed at irregular intervals.

E. If woody vegetation is used, it should be placed along the banks and edges of the bioretention system, not in the direct flow path.

F. Only species well adapted to the regional climate must be used.

G. Species planted in well-drained media must be tolerant of short-term ponding as well as periods of low soil moisture.

3.1.3 Design Procedure

The following procedures are intended to guide an applicant through the design of a shallow bioretention system:

3.1.3.1 Design Steps

- *Step 1* – Determine if the development site and conditions are appropriate for the use of a shallow bioretention system. Consider the Application and Site

Feasibility Criteria in Subsections 3.1.1.2 (Physical Constraints) and 3.1.2.2 (Location and Siting).

- *Step 2* – Determine the drainage area and its equivalent impervious area (EIA). Table A-1 can be used to estimate the EIA [EIA = C x Drainage Area].

- *Step 3* – Compute the maximum retention volume that will be detained in the surface storage of the shallow bioretention system (less than 12 inches).

- *Step 4* – Set design elevations and dimensions of facility. See Subsection 3.1.2.3.

- *Step 5* – Design a pretreatment system if practicable — either a prefilter strip, vegetative swale, or other measure.

- Step 6 – Design the system to meet the recovery requirements in 3.1.2.5.

- *Step 7* – Design the emergency overflow. An overflow must be provided to bypass and/or convey larger flows to the downstream drainage system or stabilized watercourse. Non-erosive velocities need to be ensured at the outlet point.

- *Step 8* – Determine the Average Annual Pollutant-Load Reduction. This annual average pollutant-load reduction for each constituent must be calculated using the retention volume determined in Step 3 and the EIA determined in Step 2.

- *Step 9* – Calculate the peak attenuation credit.

- *Step 10* – Prepare the vegetation and landscaping plan. A landscaping plan for the detention area should be prepared to indicate how the area would be established with vegetation.

3.1.3.2 Design Example

Assume that a stormwater BMP is needed to help meet the water quality objectives of a site. The site includes 1 acre of paving that is not suitable for pervious pavement and 1 acre of landscaped area with a CN of 78. The seasonal high water table is found to be 2 feet below the surface. The following are sample calculations for sizing a detention with shallow bioretention system:

- *Step 1* – Assume that the applicant has determined that the site meets the criteria specified in 3.1.1.2. Therefore, a shallow bioretention system is an appropriate choice for a BMP on this site.

- *Step 2* – The contributing area is a 1-acre paved surface and 1-acre pervious service with a CN of 78. The 1-acre paved service can be considered DCIA. Therefore based on Table A-1, using 50% DCIA and a NDCIA CN of 78, the mean annual runoff coefficient (C) can be estimated to be 0.466. The EIA for 2 acres with C of 0.466 acre is 0.932 acre [0.466 * 2].

- *Step 3* – The area available for the shallow bioretention system is limited to approximately 80 feet by 30 feet (Area at top of storage = 80 * 30 = 2400 sf). Therefore, using the maximum detention depth of 1 foot, and assuming a side slope of 3:1 (area and bottom of storage = 74 * 24 = 1776 sf) the maximum detention volume detained on the surface of the biofiltration area is calculated to be 2,088 [((2400 sf + 1776 sf)/2) * 1 foot)] cubic feet. .

- *Step 4* – The design elevations are then set to meet the criteria specified in 3.1.2.3.

- *Step 5* – Assume that the applicant has found that there is sufficient space for a prefilter strip. This reduces the frequency of infiltration rate testing to once every 3 years, rather than once every 18 months, which is required if no prefilter strip is included.

- *Step 6* – The applicant runs the appropriate recovery analysis under seasonal high water table conditions and determines that the system can recover in 36 hours. This meets the criteria detailed in 3.1.2.5

- *Step 7* – An emergency overflow and the appropriate erosion controls would then be designed to meet the discharge from the 100-year/24-hour design storm event in Sarasota County.

- *Step 8* – The average annual pollutant removal efficiency would be calculated. Dividing the detention volume by the EIA gives a detention volume of 0.62 inch over the EIA. Figure 3.1-3 shows that approximately 50% of the average annual runoff would be retained and infiltrated by the shallow bioretention systems.
- *Step 9* – The applicant would then calculate the peak attenuation credit. Two options are available:

3.1.4 Operation and Maintenance

3.1.4.1 Maintenance

Several ways to maintain the system and to continue to receive stormwater credits include:

A. Prune and weed to keep any structures clear.

B. Maintain/mow the prefilter or swale at least twice during the growing season and remove clippings from the flow path.

C. Replace mulch where needed when erosion is evident.

D. Remove trash and debris as needed.

E. Replace mulch over the entire area every 2 to 3 years.

F. Remove sediment from inflow system and outflow system as needed.

G. Stabilize any upstream erosion as needed.

H. Remove and replace any dead or severely damaged vegetation.

3.1.4.2 Inspection

The operation and maintenance entity is required to provide for the inspection of the total surface water management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections shall be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter. The report is due within 30 days of the date of inspection. At a minimum the following should be inspected:

A. Inspect inflow/outflow points for any clogging.

B. Inspect prefilter strip/grass channel and bioretention area for erosion or gullying.

C. Inspect trees and shrubs to evaluate their health.

D. Inspect the underdrain system.

3.1.4.3 Testing

Testing must be conducted by the appropriate Florida-registered and -licensed professional to provide reasonable assurance that the shallow bioretention system is functioning as intended. Results as well as remedial actions should be reported to SWFWMD and Sarasota County. Formatting requirements and details on how reports should be submitted must be discussed and agreed to during the permitting procedure. For sites that include a large number of bioretention systems, a testing schedule in which a representative sample of bioretention systems are tested at the appropriate interval may be agreed to at the pre-application meeting or during the permitting process. Testing must include the following:

A. The planting soils pH must be tested every 3 years. Planting soils pH should be between 5.5 and 6.5. If soil pH is below 5.5, lime must be applied to raise the pH to 6.5.

B. Bioretention systems that include a prefilter strip require that a double-ring infiltration test be performed every 3 years at three locations in the bottom of the basin to confirm design infiltration rates. Bioretention systems that do not include a prefilter strip require that a double-ring infiltration test be performed every 18 months at three locations in the bottom of the basin to confirm design infiltration rates. If two out of three tests are below the design criteria (Section 3.1.2.5) or the average rate of the three tests is below the design criteria, the mulch layer and surficial soil layer must be restored. Core aeration or cultivating of non-vegetated areas may be sufficient to ensure adequate filtration.

3.1.4.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of a shallow bioretention system. Maintenance responsibility for all LID and stormwater facilities must be vested in a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.1.5 References

1. Saxton, K.E., and W.J. Rawls, 2006. Soil Water Characteristic Estimates by texture and Organic Matter for Hydrologic Solutions. *Soil Sci Soc Am J* 70:1569-1578. (http://hydrolab.arsusda.gov/soilwater/Index.htm)
2. St. Johns River Water Management District (SJRWMD). 1983. *Special Publication: SJ93-SP10: Full-Scale Hydrologic Monitoring of Stormwater Retention Ponds and Recommended Hydro-Geotechnical Design Methodologies.* Pg. 162. sjr.state.fl.us/technicalreports/pdfs/SP/SJ93-SP10.pdf

SECTION 3.2: Pervious Pavements

3.2 PERVIOUS PAVEMENTS

Key Considerations	**Practice Intent:** ▪ Reduce stormwater runoff production while supporting traffic loading. **Design Criteria:** ▪ Must use a certified installer. ▪ Must use a flat or minimal slope area. ▪ Must incorporate a perimeter edge restraint. ▪ Must use in-situ infiltration measurements. ▪ Typically include a surface pavement overlaying a reservoir. **Advantage/Benefits:** ▪ Has potential to reduce the size of or eliminate stormwater structures from impervious areas. ▪ Increases usable/developable space or decreased developed footprint. ▪ May increase aesthetic value. **Disadvantages/Limitations:** ▪ May have increased maintenance requirements and costs. ▪ Typically has higher construction cost than conventional impervious pavements. ▪ Not suitable for all site soil conditions. ▪ If the surface fails, it must be reconstructed, not resurfaced. **Maintenance Requirements:** ▪ Vacuum as needed when infiltration measurements are lower than 1.5 inches per hour. ▪ Designate a legally responsible authority for maintenance.
Pollutant Removal Potential	**H** **Total Suspended Solids** **M-H** **Nutrients**—Total Phosphorus/Total Nitrogen Removal (with additional nutrient absorption media) **H** **Metals**—Cadmium, Copper, Lead, and Zinc removal **No data** **Pathogens**—Coliform, Streptococci, E.Coli removal
Stormwater Management Suitability	☒ **Water Quality** ☒ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Yes **High-Density/Ultra-Urban:** Yes **Traffic Considerations:** Typically for light duty and low-frequency traffic. **Shallow Water Table:** Precautions needed. **Soils:** Well-drained soils.
Other Considerations:	ADA and Florida Building Code Compliance

L—Low, **M**—Moderate, **H**—High

3.2.1 General

3.2.1.1 Overview and Intent

Pervious pavement (also commonly referred to as *permeable pavement* and *porous pavement*) systems are pavement systems that infiltrate and temporarily store part or all of the water quality volume. Pervious pavement systems infiltrate and capture rainfall that falls on the surface at rates up to the surface infiltration rate; these are contrasted to impervious pavements where almost all direct rainfall becomes runoff. Pervious pavement systems infiltrate water below the surface where water is typically allowed to exfiltrate into the surrounding parent soil. Under these circumstances, pervious pavement systems function as *retention systems*. Pervious pavement systems should be considered as part of a treatment train, with credit based on available storage volume and the ability of the system to readily recover the storage volume.

Many pervious pavement surface materials are available for different aesthetic considerations and costs. Pervious pavements surface materials can be divided into two groups: modular pavers and cast-in-place pavements. Figure 3.2-1 shows common pervious pavement surface materials. Profiles of modular block pervious pavements systems typically include three layers: surface layer, filter layer, and reservoir layer. Cast-in-place systems can either be incorporated into the three-layer design, a two-layer design (eliminating the filter layer), or be designed as a single continuous layer of the surface material directly over the parent soil, without a separate reservoir layer.

(a) (b) (c)

Figure 3.2-1 Common Pervious Pavement Materials: a) Permeable Interlocking Concrete Pavers, (b) Porous Concrete, (c) Flexi-pave™

In single-layer profile systems, water is stored below the surface, within the material's pore space, and then exfiltrates out of the profile. In multi-layer profiles, water is stored in the reservoir layer pore space until it exfiltrates into the surrounding parent soil. Filter layers often consist of coarse sand or small aggregate (i.e., pea gravel), which helps stabilize modular paver surfaces (see Figure 3.2-2.) In Sarasota County a nutrient-absorption layer is required to be installed between the parent soil and the pervious pavement system. The intent of this layer is to reduce pollutant loading to the groundwater.

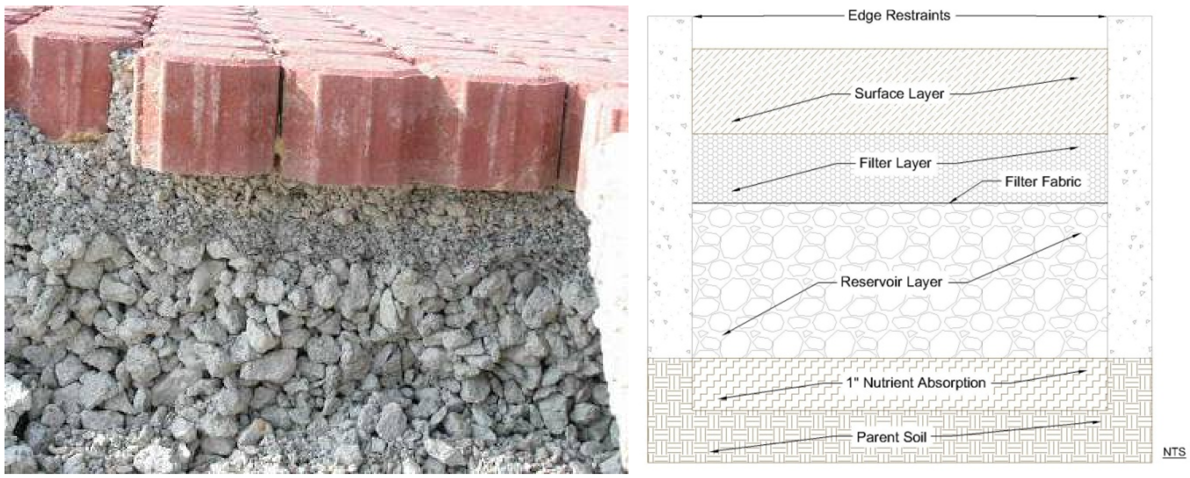

Figure 3.2-2 Typical Modular Paver Pervious Pavement System Cross Sections

3.2.1.2 Applicability

Typical Applications

Typically, pervious pavements are used for low-traffic loading (less than 100 vehicles per day) and low-turning areas, such as parking spaces; residential street parking; cart, bicycle, and pedestrian paths; driveways; and emergency-vehicle-access lanes (Figure 3.2-3).

(a) (b) (c)

Figure 3.2-3 Examples of Pervious Pavement (a: Parking Lot, b: Driveway, c: Walking Path)

Pervious pavements (such as modular pavers) can be designed to support heavier traffic loads. However, certain pervious pavement materials (such as pervious concrete) are susceptible to structural failure due to shear stress on the surface. Caution should be used when designing pervious pavement in areas subjected to high volumes of vehicular traffic, frequent braking, or frequent turning. To address this concern, pervious pavements can be incorporated with traditional impervious pavements to provide a more durable surface in certain areas, while infiltrating runoff in other areas. For example, drive paths and turning areas in a parking lot could be impervious, while the parking spaces, the parking lot perimeter, and areas in front of parking stops could be pervious.

3.2.2 Design Considerations and Requirements

3.2.2.1 Structural Considerations and Requirements

This manual only provides requirements pertaining to the hydraulic functioning of pervious pavements, Therefore the applicant should be diligent in determining if the application of the pervious pavement system is appropriate for the design’s structural capability.

3.2.2.2 Hydraulic Considerations and Requirements

For a pervious pavement area to be permitted as part of the stormwater treatment system, an appropriate Florida-registered and -licensed professional must demonstrate that the pervious pavement meets all the following hydraulic requirements:

Infiltration and Storage Requirements

A. The surface must be maintained to prevent significant clogging and improve infiltration rates. A surface infiltration rate of at least 1.5 inches per hour is required. Tests must be conducted biennially in August or September and certified by an appropriate Florida-registered and -licensed professional.

B. At least two (maximum of 10 for a site) testing locations per acre must be installed into the pervious pavement system to measure the surface infiltration rates of the pervious pavement system. An example of a devise that has been shown to be effective is the Embedded Ring Infiltrometer Kits (ERIKs - Wanielista and Chopra, 2007).

C. Sloping pervious pavement surfaces must be minimized. It is recommended – but not mandated – for parking lots and vehicular traffic areas with pervious pavement to be flat and not to exceed a slope of 0.5%.. Sidewalks, walking, cycling, and cart paths are permitted to have slopes not exceeding 5%. No volume above the lowest elevation of a sloped pervious pavement surface must be included in the pervious pavement system storage volume. Applicants must also consult other appropriate regulations governing pavement surface slopes.

D. Parking lots and other vehicular traffic areas (excluding road right of ways, pedestrian walks and bicycle paths) must be constructed to produce 2 inches of nuisance ponding above the surface or above the lowest surface elevation of a sloped surface before overflow is permitted. *Nuisance ponding* is non-hazardous ponding designed to provide a visible warning that the pervious pavement system has failed and that remediation will be required.

E. Designs will be assumed to achieve Annual Mass Removal Efficiency consistent with the Dry Retention Depths found in Table A.3, provided it can be demonstrated that the surface infiltration rate is greater than or equal to 1.5 inches per hour and that the area of the Pervious Pavement System is assumed to have a CN =80.

F. A 1-inch nutrient absorption layer must be installed between the pervious pavement system and the parent soil (excluding sidewalks, walking, cycling, and cart paths).

G. The infiltration rate of the parent soil is essential to the function of the pervious pavement system. If the parent soil has a low infiltration rate and the compaction of the predevelopment soil exceeds 95% Modified Proctor Density, the soil must be scarified to a minimum depth of 16 inches, re-graded, and proof rolled to a maximum of 95% Modified Proctor Density.

Discharge Requirements

A. For flood control, the pervious pavement system storage available after a 36 hour drawdown time can be used in the flood control calculation. The Applicant can account for this storage by including the available storage as soil storage in the sites weighted CN or accounting for this storage into the available Pond storage for the site.

B. Appropriate downstream detention must be provided if a pervious pavement system cannot provide sufficient runoff reduction to meet its flood control requirements.

C. Appropriate downstream erosion controls must be provided for potential pavement discharge.

Recovery Requirements

A. Outlet structures must allow for 2 inches of nuisance ponding for parking lots and vehicular traffic areas (excluding road right of ways, pedestrian walks and bicycle paths).

B. The Seasonal High Water Table (SHWT) must be at least 12 inches below the bottom of the pervious pavement system profile (excluding the nutrient-absorption layer).

C. The storage volume used to estimate the average annual load reduction must be recovered within 72 hours under SHWT conditions.

D. The storage volume used to determine the CN or Rational C calculation (for flood-control credit) must be recovered within 36 hours under SHWT conditions.

E. An appropriate Florida-registered and -licensed professional must perform a recovery analysis using site-specific geotechnical data to determine storage recovery. For guidance on the number of borings refer to SJ93-SP10 (SJRWMD 1993).

F. A safety factor of 2.0 or more must be applied to the recovery analysis to allow for geological uncertainties. This can be achieved by dividing the measured soil hydraulic conductivity rate by the safety factor or demonstrating recovery within 36 hours.

3.2.2.3 Maintenance Requirements

A. The surface of the pervious pavements can become clogged with fine particles and material that must be removed to optimize surface infiltration rates. Improper design or construction can also result in premature failure of the pavement surface (i.e., fractures, settling, shifting, etc.).

B. If surface infiltration rates measured using the installed testing location are less than 1.5 inches per hour, maintenance must be performed to recover the surface infiltration rates. Maintenance typically involves using a vacuum truck to remove clogging material. However, less-accessible systems, such as driveways or walking, cycling, or cart paths, may use alternative means (excluding any form of pressure washing), such as industrial-type vacuums or sweepers, to recover surface infiltration rates.

3.2.2.4 Safety Considerations

A. Restrictions prohibiting excessive traffic weight, use of abrasives, and resurfacing should be clearly posted.

B. Certain pervious pavement surfaces may be difficult to traverse for individuals who have physical disabilities. Void spaces filled with filter material can cause the pavement surface to be uneven and especially difficult for those using crutches, walkers, or high-heeled shoes.

3.2.2.5 Additional Design Considerations

A. Edge restraints must be installed around pervious pavement areas to prevent failure along surface edges and to impede horizontal movement of water below the pavement surface. The edge restraints must extend to the bottom of the reservoir material.

B. Runoff from adjacent landscaped areas must not be directed onto the pervious pavement system.

3.2.3 Example Pervious Pavement Design Procedure

Pervious pavement design has two main components: structural design and hydraulic design. The pavement system must be able to support the traffic loading while also—and equally important—functioning properly hydraulically. This manual does not discuss structural designs of pervious pavement systems. Readers should consult pavement design standards to ensure that pervious pavements will be structurally stable. The criteria in this manual are **minimum** standards for designing a pervious pavement system in Sarasota County. Readers should consult with appropriate County and State agencies for any variations or additions to these criteria.

3.2.3.1 Hydraulic Design

- *Step 1* – Decide on the Required/Desired Removal Efficiency

  Pervious pavement system design has a number of design dependent variables; therefore, the design professional must first determine which design variables are defined by the specific site restraints. The first decision the designer will have to know is if the system will be designed to meet a desired Annual Pollutant Load Removal to be consistent with the "Net Improvements Standards" of Impaired Waters or if the designer is interested in the Removal Efficiency of the design.

  If the Annual Pollutant Load Removal is the approach desired then the designer must know the Meteorological Zone, the Mean Annual Rainfall, the Pre Developed Land Use, and the Post Developed Land Use, along with the typical site hydrologic characteristics. This information is used to determine the Annual Mass Loading for Nitrogen and Phosphorus for both the Pre Developed and Post Developed Conditions. Then in turn the required treatment efficiency may be calculated to meet the "Net Improvement" criteria. The Event Mean Concentration for General Land Use Categories in Florida can be found in Table A-4.

If the site is not located in an Impaired Water Body then the required Water Quality Annual Pollutant Load Removal Efficiency is 80%.

- *Step 2* – Determine which variables are fixed by Site restraints.

  The variables that are dependent on the design and needed to calculate the efficiency of the pervious pavement system are the Post Developed DCIA, the Post Developed Non-DCIA CN, the area of pervious pavement, and the storage in the pavement system. To optimize the system and to meet the required Removal Efficiency determined in Step 1 it may require the designer complete a number of iterations. The required number of iterations will be reduced by determining as many of these variables from site specific characteristics. Some of the items that could be considered are:

  What is the maximum area available area where Pervious Pavement could be used on the site?

  What is the minimum Pervious Pavement Section that can be used to accommodate the proposed loads?

  What is the maximum Pervious Pavement Section that can be used to maintain an adequate separation from the SHWT?

- *Step 3* – Calculate the remaining variables

  The Pervious Pavement System is assumed to have similar Annual Mass Removal Efficiencies as a Dry Retention area, therefore the remaining variable(s) can be determined from the information in Table A-3.

- *Step 4* – Verify Storage Recovery Time

A recovery analysis would be needed to demonstrate that the pervious pavement system meets the requirements listed in Section 3.2.2.2, Recovery Requirements. The design may have to be revaluated if the storage recovery time is not met.

- *Step 5* – Determine the Flood Protection benefit of the Pervious Pavement System

  The pervious pavement system storage that is available after 36 hours of recovery can be accounted for in the flood protection/ attenuation calculations. There are two methods that this storage volume can be evaluated:

  1. The available pervious pavement storage can be evaluated as “soil storage” when calculating the weighted CN for the Site, or

2. The pervious pavement area can be included in the DCIA calculations and the storage can be evaluated as “Pond Storage”.

3.2.3.2 Design Emergency Overflow

A pervious pavement system may overflow during extreme rainfall events or if a pervious pavement fails. An adequately sized emergency overflow must be constructed to meet the following criteria:

A. Emergency overflow systems must be incorporated into parking lots and vehicular traffic areas to produce at least 2 inches of nuisance ponding over the pavement surface or over the lowest elevation of the surface for sloped pavements.

B. Emergency overflow systems must be sized to convey runoff from the pervious pavement system that would occur from the design storm.

C. Driveways, walking, cycling, and cart paths are not required to have an overflow structure.

3.2.3.3 Example Design Problem

The following design problem is intended to illustrate how an applicant could demonstrate the effectiveness of the pervious pavement as part of a stormwater treatment system. In most applications the pervious pavement would only be a part of the stormwater treatment system and the ability of the entire system to meet the applicable stormwater criteria would have to be demonstrated.

Problem Statement

The example site is a 2-acre parking lot for a proposed Low-Density Commercial development that will receive no additional runoff from adjacent areas. The site was previously an Upland Mixed Forest on soils corresponding with the Hydrologic Soil Group B/D. The seasonal high water table in this location is approximately 18 inches below the surface. The site is located in Sarasota County which falls within the Meteorological Zone 4 and has a Mean Annual Rainfall of 52 inches. The pre developed curve number (CN) is 78.

- *Step 1* – Decide on the Required/Desired Removal Efficiency

  It will be assumed for this example that the site is located in an Impaired Water Body, therefore the design will be to demonstrate a “Net Improvement”. Using Table A-4, the mean Total N and Total P (mg/l) concentrations can be looked up for the site Pre and Post Land Uses.

Upland Mixed – Total N = 0.676 mg/l and Total P = 2.291 mg/l

Low Density Commercial – Total N = 1.18 mg/l and Total P = 0.179 mg/l

- *Step 2* – Determine which variables are fixed by site restraints

For this example it will be assumed that the site traffic loading is such that the entire parking lot could be designed to be pervious pavement and that a 4" pavement thickness is sufficient to provide the desired load strength. If possible it is determined by the applicant that due to an occasional heavier loading and/or more turning movements that it would be beneficial if at least 30% of the parking lot could be traditional impervious pavement. It is also assumed that the site requires minimal fill, therefore the bottom of the proposed pavement will be assumed to be at the existing grade. Since the SHWT is 18 inches below the existing grade and it is required to maintain 12 inch separation between the SHWT that the bottom of the pervious pavement system there is 6 inches available to be used for the pervious pavement reservoir. Given a 4 inch thick pervious concrete (Void space 20%) and a 6 inch thick #57 stone pavement reservoir (Void space 25%) the inches of pavement storage (S) can be calculated.

S = (4" * 0.20) + (6" * 0.25) = 2.3"

The pre developed Annual Runoff Coefficient, Annual Runoff, and Annual Mass Load can also be calculated.

The pre developed Annual Runoff Coefficient (C) interpolated from Table A.1, given a CN of 78 and a DCIA of 0%. C = 0.12 (rounded to the nearest 100^{th})

The Annual Runoff (AR in ac. ft / year) = Annual Rainfall (in / year) * Area (ac) * C * (1 ft. / 12 inch)

AR = 52 * 2 * 0.12 / 12 = 1.04 ac. ft / year

The Annual Mass Load (AML in kg/year) = AR * 43,560 ft^2 / ac * 7.48 gal/ft^3 * 3.785 l/gal * Concentration (mg/l) * (1 kg/ 10^6 mg).

$AML_{N\text{-}pre}$ = 1.04 * 43560 * 7.48 * 3.785 * 0.676 / 10^6 = .867 kg/year

$AML_{P\text{-}pre}$ = 1.04 * 43560 * 7.48 * 3.785 * 2.291 / 10^6 = 2.938 kg/year

- *Step 3* – Calculate the remaining Variables.

  In this example of a 2 acre parking lot it will be assumed that the portion of the parking lot that is not pervious pavement is impervious, therefore will be calculated as DCIA. It is also assumed that even though the pervious pavement section could be used for the entire parking lot there are areas of the parking lot that may on occasion experience heavier loading and/or more turning movements, therefore these areas may be better served if designed to be impervious pavement. To calculate the required Annual Mass Removal to meet the Net Improvement criteria and to calculate the available pervious pavement storage the area to be pervious pavement must be defined. In this example the desired 30% traditional impervious pavement will be assumed for the percent DCIA then it can be calculated if the required Net Improvement will be met.

  From Table A.1 - the post C, given CN = 80 and DCIA = 30% = 0.338

  The Post AR = 52 * 2 * 0.338 / 12 = 2.929 ac. ft / year

  $AML_{N\text{-}post}$ = 2.929 * 43560 * 7.48 * 3.785 * 1.18 / 10^6 = 4.263 kg/year

  $AML_{P\text{-}post}$ = 2.929 * 43560 * 7.48 * 3.785 * 0.179 / 10^6 = 0.647 kg/year

  The required removal efficiency to meet the Net Improvement is determined from the AML's calculated for Nitrogen in this example.

  Required Efficiency (E %) = (1 – (AML_{pre} / AML_{post})) * 100

  E% = (1 – (0.867 / 4.263)) * 100 = 79.7%

  The Required Retention Depth can then be determined using Table A.2 given CN = 80 and DCIA = 30%.

  At a Retention Depth of 1" the E% = 78.6 and at a Retention Depth of 1.25" E% =83.2
  Interpolating the required E% of 79.7 between 78.6 and 83.2 it is calculated that the Required Retention Depth = 1.06" from the contributing drainage area.

  Therefore the required treatment storage = Area * Retention Depth * 43560 / 12 = 7679 cf.

  The provided pervious pavement = pervious pavement area * S * 43560 / 12

Since 30% was used for the assumed DCIA the parking lot is 70% pervious pavement or 2 ac * .7 = 1.4 ac.

Provided Storage = 1.4 * 2.3 * 43560 /12 = 11,688 c.f.

The provided storage is greater than the required storage therefore the system meets the Net Improvement requirement.

- *Step 4* – Verify Storage Recovery Time

  A recovery analysis would be needed to demonstrate that the pervious pavement system meets the requirements listed in Section 3.2.2.2, Recovery Requirements. The design may have to be revaluated if the storage recovery time is not met.

- *Step 5* – Determine the Flood Protection benefit of the Pervious Pavement System

  The pervious pavement system storage that is available after 36 hours of recovery can be accounted for in the flood protection/ attenuation calculations. There are two methods that this storage volume can be evaluated:

  The available pervious pavement storage can be evaluated as "soil storage" when calculating the weighted CN for the Site, or

  The pervious pavement area can be included in the DCIA calculations and the storage can be evaluated as "Pond Storage".

3.2.4 Construction

3.2.4.1 Soil Excavation

A. Compacting the parent soil will reduce the exfiltration rate from the storage layer and therefore should be avoided. To reduce the risk of compaction, heavy equipment should not be allowed onto the parent soil. The maximum allowable soils compaction is 95% Modified Proctor Density (ASTM D-1557) to a minimum depth of 24 inches.

B. If compaction of the predevelopment soil exceeds 95% Modified Proctor Density, the soil must be scarified to a minimum depth of 16 inches, re-graded, and proof rolled to a maximum of 95% Modified Proctor Density.

3.2.4.2 Aggregate Installation

A. The nutrient-absorption layer must be between the parent soil and pervious pavement system. The nutrient-absorption layer should meet the following requirements unless it can be demonstrated that the proposed media provides an equal or greater level of nutrient reduction:

1. Thickness should be at least 1 inch.
2. Unit Weight should be no more than 70 pounds per cubic foot when dry.
3. No more than 5% of the particles should pass through a #200 sieve.
4. Over 50% of the material (by volume) should be uniformly graded sand and should contain no shale.
5. Water holding capacity should be at least 30% (as measured by porosity).
6. Vertical permeability should be greater than 2 inches per hour at the specified unit weight noted above.
7. Organic content should be no more than 5% by volume.
8. Media pH should be between 6.5 and 8.0.
9. The concentration of soluble salts should be less than 3.5 g (KCL)/L.
10. The sorption capacity of the media should be greater than 0.005 mg OP/mg media.

B. Aggregate for the reservoir layer must be washed No. 57 size material, with inert chemical properties. Quartz can be used in areas where available. If the aggregate contains fine particles, the interface between the reservoir layer and parent soil can become clogged. Aggregate must be installed in layers to achieve the required strength. Crushed shell and limestone must not be used in or below the pervious pavement system.

C. To prevent settling into the lower layer, a woven or non-woven geotextile must be installed between the reservoir layer and the parent soil and between the reservoir layer and the filter layer when coarse sand is used.

D. If used, the filter-layer material must trap fine material but to still allow rapid drainage. Examples of this filter-layer material include washed pea gravel or coarse sand.

3.2.4.3 Pavement Installation

The pervious pavement must be installed by a contractor certified by the pervious pavement product manufacturer to install the pervious pavement specified. Modular pavers can be installed manually or mechanically. Modular pavers are laid over the filter layer and the void spaces are then backfilled with filter material.

3.2.5 Operation and Maintenance

The operation and maintenance entity is required to provide for the inspection of the total surface water management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections shall be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter. The report is due within 30 days of the date of inspection.

3.2.5.1 Maintenance

Excessive rainfall can overwhelm a pervious pavement system either by intensity (limited by surface infiltration rate) or depth (limited by storage volume). Ponding due to rainfall intensity exceeding the surface infiltration rate should begin to be alleviated once the rainfall rate falls below the surface infiltration rate. However, reduced surface infiltration rates may prolong the ponding duration, indicating that maintenance is needed. Frequent ponding may indicate that the storage volume is not recovering in the required length of time to be able to store water from subsequent events. This could be due to loss of porosity in the pervious pavement profile, reduced exfiltration rates into the parent soil, or other failures in the pervious pavement system that, without nuisance ponding, may be easily overlooked. The duration and date of occurrence of any nuisance ponding must be documented in the maintenance records.

Pervious pavement systems must be maintained by removing clogging material from the surface to maintain optimum surface infiltration rates. Vacuuming systems on vehicles are often used for large pervious pavement areas where the vehicles' movement is not limited. The surface must not be pressure washed to remove clogging material since pressure washing can force clogging material deeper into the pervious pavement system where it is more difficult to extract, thus permanently reducing infiltration rates. Alternative methods (such as industrial vacuum cleaners) for removing clogging material from less-accessible installations, such as walking, cycling, and cart paths or driveways, may be permissible as long as surface infiltration rates are improved and are greater than the threshold 1.5 inches per hour. Follow-up infiltration rate measurements, to ensure that the infiltration rate exceeds 1.5 inches per hour, are required. Any surface shifting or cracking should be promptly repaired. Filter material removed during vacuum sweeping should be replenished with material that meets the specifications of the original filter material.

3.2.5.2 Inspection

At a minimum the following should be inspected:

A. The surface should be inspected for any compromised sections of the pavement. Compromised sections should be addressed, whether fractured, shifted, or otherwise damaged and should be repaired as needed.

B. The surface should be inspected for the accumulation of sediments and other cogging material.

C. Voids should be inspected for missing aggregate. Missing aggregate should be added to the pavement surface as needed.

3.2.5.3 Testing

The rate of clogging material accumulating will vary based on location and traffic. Surface infiltration rates must be tested biennially, during August and September (SHWT most likely), to ensure that rates are not limiting the performance of the system. If surface infiltration rates are less than 1.5 inches per hour, maintenance must be performed for the respective areas. Ideally, if one area was maintained, all areas should be maintained at the same time.

3.2.5.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of pervious pavement systems. Maintenance responsibility for a pervious pavement must be vested in a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.2.6 References

1. Natural Resource Conservation Service (NRCS). 1986. *Urban Hydrology for Small Watersheds: TR-55 (TR-55).* http://www.wsi.nrcs.usda.gov/products/w2q/H&H/docs/other/TR55_documentation.pdf
2. St. Johns River Water Management District (SJRWMD). 1983. *Special Publication: SJ93-SP10: Full-Scale Hydrologic Monitoring of Stormwater Retention Ponds and Recommended Hydro-Geotechnical Design Methodologies.* Pg. 162. sjr.state.fl.us/technicalreports/pdfs/SP/SJ93-SP10.pdf
3. Wanielista, M. and M. Chopra. 2007. *Performance Assessment of Portland Cement Pervious Pavement: Report 1 of 4: Performance Assessment of Pervious Concrete Pavements for Stormwater Management Credit.* http://www.stormwater.ucf.edu/research/Final Report 1 of 4 Performance Assessment and Credit Feb.doc

CHAPTER 3.3: Stormwater Harvesting

3.3 STORMWATER HARVESTING

Key Considerations	**Practice Intent:** ▪ Reduce runoff volume and the mass of pollutants before surface water discharge. **Design Criteria:** ▪ The equivalent impervious area for a watershed must be calculated. ▪ A percent of runoff volume not discharged is specified and is called the *harvesting efficiency* (E). ▪ The Rate-Efficiency-Volume (REV) curve is used to specify the storage volume and the harvesting rate. ▪ The harvesting rate is calculated for irrigation but the rate can be calculated for other uses. ▪ For surface ponds, the permanent pool elevation is calculated at the normal groundwater elevation. The pond discharge elevation is at the top of the harvesting volume. ▪ The irrigation method (drip or spray) must be specified. **Advantage/Benefits:** ▪ Improves the pollutant removal efficiency of wet detention facilities. ▪ Can meet pollution- and volume-control targets. ▪ Can be used as part of a treatment train. ▪ Can be used to replace reliance on other stressed sources or potable water. ▪ Can be planned as an aesthetic feature. ▪ Can use purple pipe but cannot mix harvesting water with reclaimed water at the same time. **Disadvantages/Limitations:** ▪ Relies on a pump and thus has to be monitored typically using a meter. ▪ Needs irrigation land about equal to the effective impervious area. **Maintenance Requirements:** ▪ Inspect and repair/replace pond and irrigation area components.
Pollutant Removal Potential	**H** **Total Suspended Solids** **H** **Nutrients**—TP, TN, OP, NO_3, NH_4 **H** **Metals**—Cadmium, Copper, Lead, and Zinc removal **M** **Pathogens**— Coliform, E.Coli removal and Cyanobacteria if used with filtration.
Stormwater Management Suitability	☒ **Water Quality** ☒ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Yes **High-Density/Ultra-Urban:** Irrigation area is limited. **Drainage Area:** Equivalent impervious area. **Seasonal High Water Table:** Must be located for pond control. **Soils:** Must be consistent with plant or lawn growth.
Other Considerations	▪ Harvesting options must be defined. ▪ Source of power for pump operation. ▪ Metering of stormwater pump. ▪ A backup source of water when harvesting volume is not available. ▪ Adjacent wetlands must not be impacted and the harvesting pond water can be used for rehydrating wetlands.

L—Low, **M**—Moderate, **H**—High

3.3.1 General

3.3.1.1 Overview and Intent

A Stormwater Harvesting System is a combination of a specified harvesting volume and rate of use intended to achieve a yearly average reduction in discharge mass. A stormwater harvesting system uses a surface detention pond or underground storage system, such as a vault, to store stormwater. The harvesting is typically for lawn irrigation and provides an alternative water source to other stressed water resources or replaces more costly potable water. Another benefit is the reduction of pollutant loads from direct discharge that helps meet total maximum daily load restrictions.

Pollutants in stormwater, either dissolved in solution or in particulate form, have been well documented. Detention, or the temporary storage of stormwater, removes some of the particulate load of pollutants. However, at a design of about a 21-day detention time, nitrogen removal is at a maximum of about 40%, and phosphorus removal is at a maximum of about 70%. The removal percentages do not increase substantially with a longer detention time. To remove additional pollutants, the associated dissolved materials can be harvested from the holding area and recycled in a watershed. When the detained stormwater is evaporated, infiltrated, or harvested, additional pollutants are prevented from discharging to downstream surface waters.

In many Florida developments, potable water can be used for irrigating lawns or to meet other non-potable uses. Per capita residential water use in Florida during 2005 was estimated to be approximately 95 gallons per day (USGS, 2008). This per capita consumption was down from 106 gallons per day in 2000. The reduction is believed to be due primarily to replacement of potable water used for irrigation (USGS, 2008). On the national level, 30% of potable water delivered to residential units is used for irrigation (EPA, 2009). Thus there is an opportunity to use stormwater to supplement the more expensive potable water used for irrigation. Approximately one-half of the reclaimed wastewater flow in 2005 was used to reduce potable quality water withdrawals for urban irrigation, agricultural irrigation, and industrial use, while one-third of the reclaimed wastewater was returned to available water supplies as aquifer recharge (USGS, 2008). Using stormwater harvesting ponds in new developments is possible because the cost of irrigating with the detained stormwater is significantly less than the cost of potable water. Also, a storage facility for stormwater harvesting is similar in design to a wet detention pond, suggesting that no additional stormwater detention area is needed. When reclaimed water is insufficient to meet water use/irrigation demands or to minimize the use of potable water for irrigation, stormwater harvesting is an option. Harvesting may also help meet Total Maximum Daily Stormwater Pollutant Load Reduction targets.

Figure 3.3-1 was developed from long-term simulated conditions to estimate the volume of water from a stormwater harvesting pond. The assumptions were that the stormwater harvesting pond volume can be added to the permanent pool or "stacked" on top of the permanent pool and that the rate of harvesting is constant but not used during periods of sufficient rainfall. Thus a shutoff valve is assumed during sufficient rainfall conditions. Figure 3.3-1 is the result of a simulation using Parrish rainfall data for the simulation. The pond was operated to provide water until the pond level was reduced to a volume equal to 1 inch over the effective impervious area (EIA). It should be noted that an additional source of water will be needed if irrigation is required when the pond level is less than the assumed minimum level. In any case, the percent of runoff water that is harvested or the removal effectiveness in terms of volume per year can be estimated.

Figure 3.3-1 is the design curve (REV) for Sarasota County. This REV curve was developed for Parrish, Florida because Sarasota County rainfall datasets were not long enough for the simulation. For specific *removal effectiveness* (E) and a *harvesting rate* (R), the *harvesting storage volume* (V) for harvesting is obtained. The stormwater harvesting storage volume is shown in the schematic in Figure 3.3-2. If a surface pond is used, the harvesting volume is above the permanent pool. Figure 3.3-3 provides a schematic for when a horizontal well is used. Figure 3.3-4 compares a horizontal and vertical well.

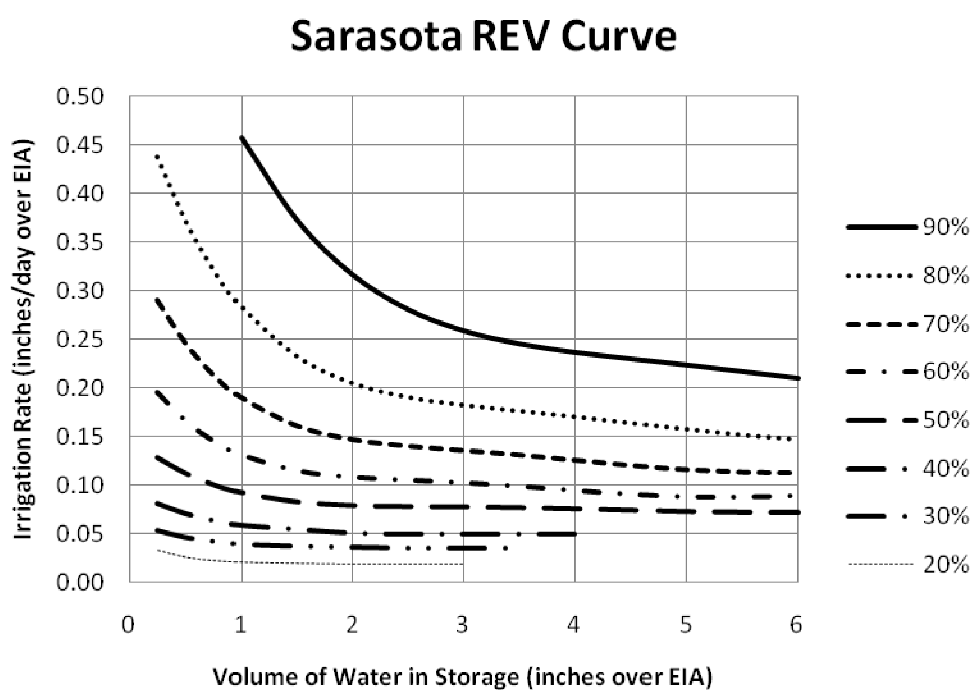

Figure 3.3-1 Rate Efficiency Volume (REV) Curve for Designing a Harvesting System for Sarasota County Florida

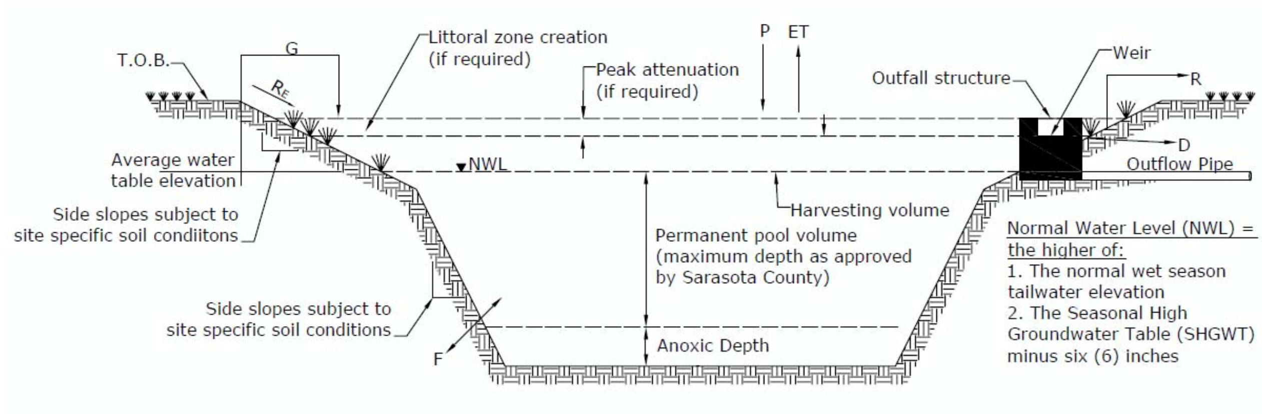

Figure 3.3-2 Schematic of Stormwater Pond with Irrigation Directly from the Pond

Legend: P = Precipitation, ET = Evapotranspiration, R = Harvesting Rate, D = Surface Discharge, R_E = Rainfall Excess, G = Supplemental Make-up Water, F = Infiltration/exfiltration to the surficial aquifer.

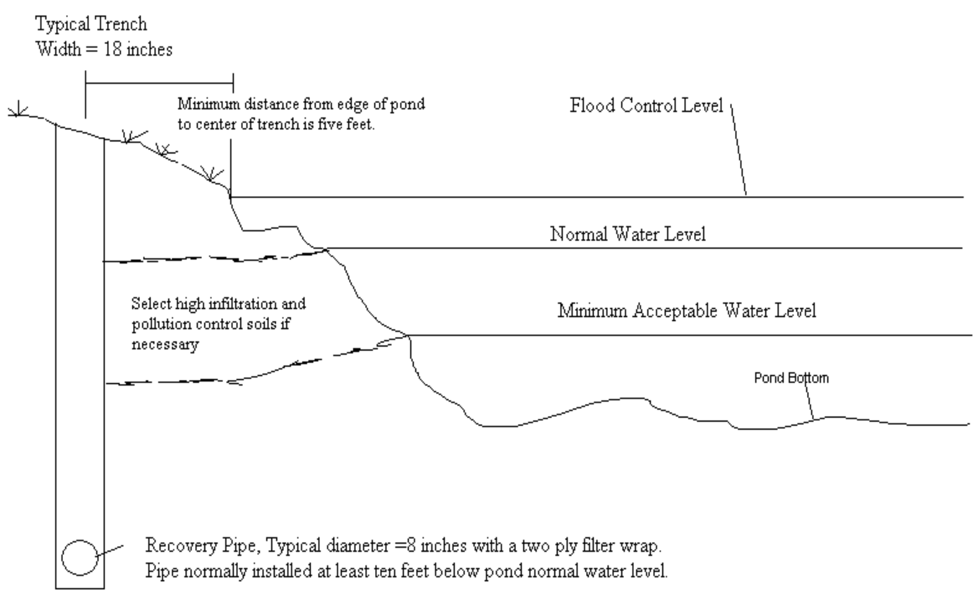

Figure 3.3-3 Horizontal Well Construction Details

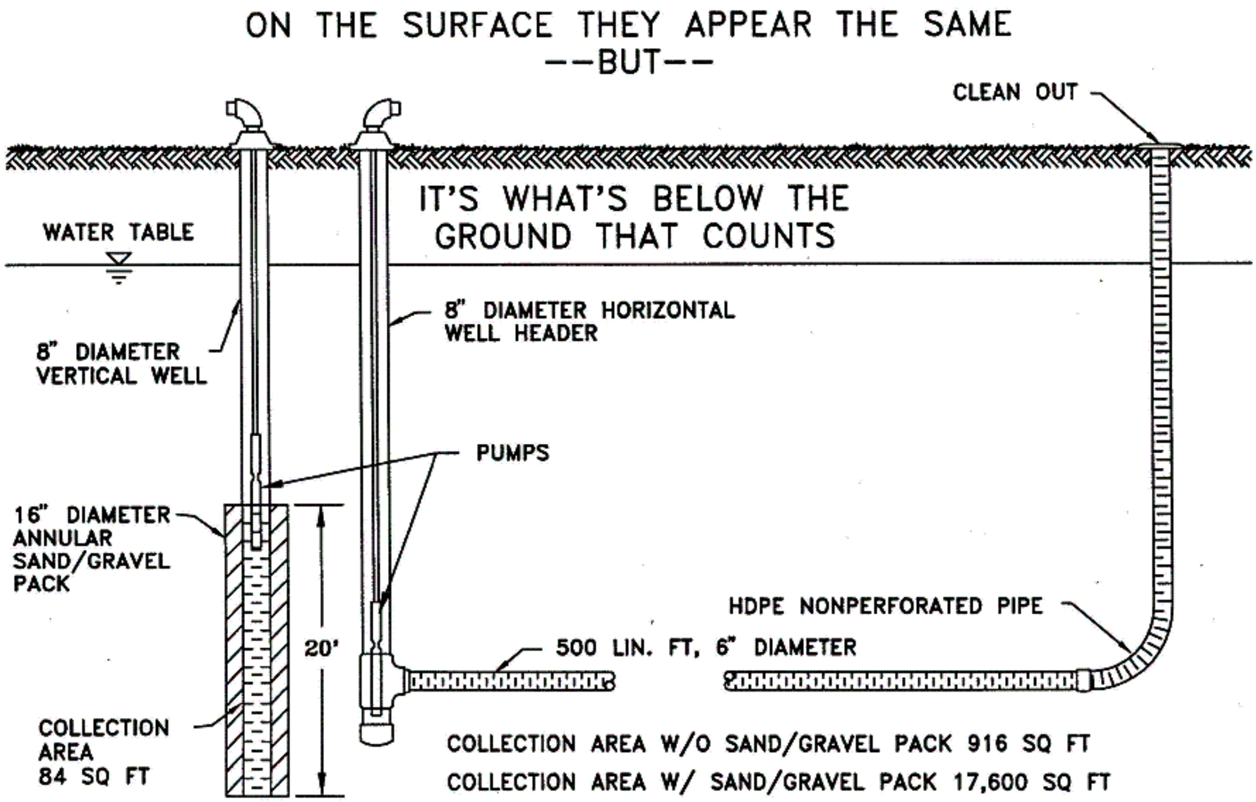

Figure 3.3-4 Comparison of a Horizontal Well and a Vertical Well

A horizontal well can be used to help filter the harvesting water before it is land applied using spray irrigation. Other equivalent filtration methods can also be used. The horizontal well is more efficient for collecting water than a vertical well and the draw-down is minimal.

3.3.1.2 Applicability

Water Quantity Control

A stormwater harvesting system is designed primarily to meet water use (i.e. irrigation) demands but can also be used to manage stormwater volume and water quality control (i.e. reduction of pollutant loads). However, a storage area is frequently a wet detention pond or other water holding areas and as such can also provide peak flow control. The pond or storage area can provide a discharge control to limit the rate of discharge. These discharge controls are typically weirs or pipes.

Water Quality Control

To achieve a desired average annual load reduction, the storage area must be designed with the target average annual volume reduction and the harvesting rate in mind. However, the system may be designed to meet water use demands if used as part of a treatment train.

General Feasibility

A. A stormwater harvesting system is usually designed to meet water use (i.e. irrigation) demands but as a side benefit, can reduce pollution loads by recycling the stormwater volume.

B. Stormwater harvesting systems most commonly use surface ponds, but in instances of limited surface area can be in-ground holding tanks or vaults.

Other Design Considerations

A. Space Required – For the harvesting storage area or identification of the underground area.

B. Filtration

1. Harvested water is required to be filtered through the equivalent of at least 4 feet of sand to minimize airborne pathogens.
2. Some irrigation systems may require an additional cartridge filter to prevent clogging.

C. Irrigation Method – Drip irrigation systems are not required to meet the requirements show above in item B 1. All irrigation systems require a precipitation shutoff.

D. Source Water – Iron forming and other clogging materials should be minimized before distribution.

E. Wetlands – Calculations must be provided on possible impacts of lower water table to surrounding wetlands.

F. Water Use Demand – The water use demands must be determined to initiate the design in accordance with Water Management District guidelines for Water Use Permit program.

G. Supplemental Water – A back-up source of water should be identified and included in the design, permitting, and installation of the water use (i.e. irrigation) system for when the harvesting water is not available. Graywater, air conditioner condensate, surficial aquifer, and reclaimed water may be used as back-up sources. Reclaimed water cannot be placed into a discharging stormwater storage area, but it can be distributed directly in the pipe without storage. A *discharging* *storage area* is defined as one that discharges flow for storm events less than the 100-year return period storm.

H. Distribution Pipe – Separate non-potable distribution water pipes must be used. The use of purple pipe for reclaimed water and harvested stormwater is encouraged, provided reclaimed and stormwater are not mixed in the same irrigation cycle and the appropriate back flow preventers are installed.

I. Metering – The volume of harvested stormwater that is used for irrigation must be metered using a flow meter (totalizer).

3.3.2 Design Considerations and Requirements

The criteria detailed below are considered **minimum** standards for the design of a stormwater harvesting system in Sarasota County. The applicant should consult with SWFWMD to determine if there are any variations to these criteria or additional standards that must be followed. If spray irrigation is used, stormwater must be filtered through 4 feet of sand or the equivalent before irrigation.

3.3.2.1 Design Considerations and Requirements

The stormwater harvesting storage (Figure 3.3-2) is that volume of water (V) necessary for sustained harvesting. When it rains, the runoff or rainfall excess is stored for irrigation. In a storage tank there is no additional harvesting volume beyond the stormwater harvesting storage volume (V), unlike the additional water storage (called the *permanent pool)* in a surface pond. A stormwater harvesting pond can have a permanent pool and a volume of water for harvesting (V) that is detained before being harvested. The permanent pool is assumed to be at the normal water level for the start of the effectiveness calculations. For harvesting effectiveness (E), the permanent pool is reduced no more than 1 inch over the equivalent impervious area. The detained water volume is called *the harvesting volume,* meaning that the water can be harvested and not discharged to downstream surface water. The permanent pool is regulated by the groundwater table or in some cases artificially regulated at a certain depth if an impermeable membrane is used between the ground and the detained water. A applicant is faced with the decision of how large to make the harvesting volume (V), the rate of harvesting (R), and the percentage of water to retain (E).

Thus the applicant of the pond has the freedom to specify the harvesting volume for particular runoff-capture efficiency or demand and then calculate the harvesting rate over an equivalent impervious area. To use Figure 3.3-1, two of the three variables must be known. The remaining variable is then calculated.

The EIA is the area of a completely impervious watershed that would produce the same volume of runoff as the actual watershed. The EIA can be calculated knowing the directly connected impervious area (DCIA) and the depth of runoff expected from the pervious area. Knowing the EIA and the rainfall depth allows the calculation of a volume of runoff. The volume of runoff is simply the product of the rainfall depth (inches) and the EIA (acres), which gives acre-inches. The volume in acre-inches can be divided by 12 to convert the units to acre-feet.

To illustrate the overall effectiveness of a stormwater harvesting pond, consider the treatment-train diagram of Figure 3.3-5. The harvesting percent is assumed at 67% of the average annual runoff and the stormwater harvesting pond is assumed to function as well as a wet detention pond or at 40% average annual nitrogen removal. The average nitrogen effectiveness when 67% of the runoff is harvested is 80%.

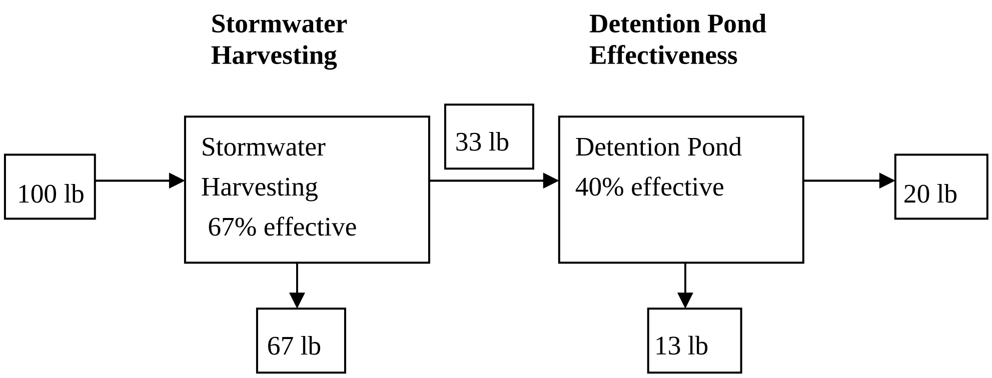

Figure 3.3-5 Example of the Nitrogen Removal Effectiveness of a Stormwater Harvesting Pond

Two removal efficiencies are noted in Figure 3.3-5, the *harvesting efficiency* (E) noted on the left side of Figure 3.3-5 as 67% and the concentration reduction noted on the right side as 40%. The overall mass-reduction efficiency (M) is specified from a post-equal predevelopment analyses, and with a known concentration removal the harvesting efficiency can be calculated and used in Figure 3.3-1. The formula for calculating the overall mass removal efficiency (M in %) as a function of the *harvesting efficiency* (E) expressed as a fraction and the concentration reduction efficiency (r) as a fraction is given as: $M = 100 [1 – \{(1-E)(1-r)\}]$.

3.3.2.2 Discharge Requirements

The effluent controls for a pond or tank are specified to achieve a post-equal predevelopment-peak discharge rate or to show no adverse increases in off-site fold levels where modeling is required. The specification may increase the size of storage beyond the harvesting volume.

3.3.2.3 Maintenance Considerations

Adequate access must be provided for harvesting systems and facilities for inspection, maintenance, and pump upkeep, including all appropriate valves, spray heads, and piping. A back-up source of water must be provided to ensure available harvesting water. Possible sources are graywater, air conditioner condensate, or reclaimed wastewater. The reclaimed wastewater is not mixed in the storage area but is used directly in the distribution line.

3.3.2.4 Safety Considerations

A. Access to the pump and harvesting storage area should be controlled.

B. Safety features may include fencing and signage.

C. Depending on the end use, electrical back-up when power is down is recommended as part of emergency operations.

3.3.2.5 Additional Permitting Considerations

A. The stormwater harvesting system will be permitted through SWFWMD's water use permit (WUP) program. The WUP will note the average annual harvest volume and source reliability for reference in ERP permit for water quality credit and condition that the harvest source water be metered.

B. The stormwater harvesting system may require a permit from the Sarasota County Health Department.

3.3.3 Stormwater Harvesting Design Example

Consider the following example to determine pollutant load removal to help understand calculation procedures.

- *Step 1* - Determining Water Demand

  Determine the pollutant load reduction based on water demand. The water shed area to be developed is 3.55 acres and has runoff to a single point of discharge. The post development condition is 70% DCIA. This would give a maximum irrigated area of 1.07 acres. Assume an average weekly demand of 0.75 inches based on Sarasota County Water Conservation Ordinance.

- *Step 2* – Computing DCIA

  The DCIA for the 3.55 acre project site is 70% or 2.48 acres.

- *Step 3* - Determining Storage Volume

  Assume that the harvesting volume is equal to 3 inches of rainfall over the watershed area.

- *Step 4* - Computing the irrigation rate

  Based on an irrigated area of 1.07 acres, water demands of 0.75 inches per week, and a DCIA/EIA of 2.48 acres, the irrigation rate would be 0.32 inches / week [(1.07*0.75)/2.48] or 0.05 inches / day.

- *Step 5* - Determining Pollutant Removal

  Using Figure 3.3-1, an irrigation rate of 0.05 inches / day and storage volume corresponding to 3 inches over the DCIA/EIA, the harvest volume/pollutant load reduction would be approximately 40%.

  The assumed effectiveness of a pond design as a function of detention time (days) is estimated from the work of Harper, 2006 or other approved methodology. The size of the pond will determine the annual detention time which is used to estimate the annual percent removal effectiveness.

  Assume that based on the detention time the wet detention pond will have remove about 65% of the total phosphorus. For these conditions, if about 40% of the runoff water is used for stormwater harvesting, the removal of phosphorus will be about 79%. The calculation for the removal is 100[1-(1-.40)(1-.65)].

- *Step 6* - Confirm Local Design Criteria and Applicability

  Other local officials and other regional or state agencies may set additional restrictions and/or surface water or watershed requirements that may apply.

- *Step 7* - Compute Peak Discharge

  The peak rate of discharge is calculated knowing the cistern volume discharge relationship, which is determined from the outflow discharge structure (weir, orifice, or the like). The peak discharge is then compared to the predevelopment discharge for design storm conditions.

- *Step 8* - Computing Pervious Area Runoff Volume

  The reason for this calculation is to determine what the runoff volume is from the pervious area of the watershed. The watershed area to be developed is 3.55 acres as runoff to a single point of discharge. The curve number for the non-DCIA area is 80, and it is assumed that this is the compacted value after development. Assume that the harvesting volume is equal to 3 inches of rainfall over the watershed area. The pervious area runoff from 3 inches of rainfall using a curve number of 80 is calculated as 1.25 inches.

- *Step 9* - Computing Post-Condition Runoff Volume and EIA

  An assumed post-development condition is 70% DCIA. The trial size of the stormwater harvesting pond is 3 inches, which can be changed to a lower or higher volume depending on the available land for pond treatment and for irrigation. The runoff from the pervious area is 1.25 inches. The runoff from the total area is the sum of the runoff from the DCIA and the pervious area or is calculated as 2.48 inches [0.70(3.00)+0.30(1.25)]. The EIA is 2.93 acres [(2.48/3.00)3.55].

- *Step 10* - Computing Average Annual Load Reduction

  Based on an irrigated area of 1.07 acres, water demands of 0.75 inches per week, and an EIA of 2.93 acres, the irrigation rate would be 0.27 inches / week [(1.07*0.75)/2.93] or 0.04 inches / day.

  Using Figure 3.3-1, an irrigation rate of 0.04 inches / day and storage volume corresponding to 2.48 inches over the DCIA/EIA, the harvest volume/pollutant load reduction would be approximately 30%.

  The assumed effectiveness of a pond design as a function of detention time (days) is estimated from the work of Harper, 2006 or other approved methodology. The size of the pond will determine the annual detention time which is used to estimate the annual percent removal effectiveness.

  Assume that based on the detention time the wet detention pond will have remove about 65% of the total phosphorus. For these conditions, if about 30% of the runoff water is used for stormwater harvesting, the removal of phosphorus will be about 76%. The calculation for the removal is 100[1-(1-.30)(1-.65)].

- *Step 11* - Confirm Local Design Criteria and Applicability

  Other local officials and other regional or state agencies may set additional restrictions and/or surface water or watershed requirements that may apply.

- *Step 12* - Compute Peak Discharge

  The peak rate of discharge is calculated knowing the cistern volume discharge relationship, which is determined from the outflow discharge structure (weir, orifice, or the like). The peak discharge is then compared to the predevelopment discharge for design storm conditions.

3.3.4 Construction

For the pond harvesting volume (V), the construction is the same as a wet detention pond; therefore, identifying the normal and seasonal high water table elevations is important:

A. If the pump is non-submersible, the pump and the flow meter (totalizer) must be placed to ensure they are not flooded.

B. The distribution system must be designed to prevent backflow of reclaimed water to the storage area.

C. Access to any mechanical equipment must be planned.

D. Safety signage must be visible.

E. A staff gauge or equivalent must be installed in the stormwater harvesting pond for visual confirmation of operation range and depths.

3.3.5 Operation and Maintenance

As conditionally required by the Water Use Permit for the stormwater harvesting system, meter readings of the water use and inspection must be submitted to the Sarasota County Government and to the Southwest Florida Water Management District. To continue to receive stormwater credit with Sarasota County the following are recommended.

3.3.5.1 Maintenance

The owner or operator should keep maintenance records or a log of activities and make them available for recertification. The records or log of activities should include data on the following:

A. Harvesting volume measured using a flow meter (totalizer).

B. Observations on the harvesting cycle times and replacement of parts.

C. Clogging frequency and maintenance of any filters.

D. Maintenance of the pump.

3.3.5.2 Inspection

As part of the maintenance log of activities, the following tasks are recommended:

A. Inspect harvesting intake lines and filter for clogging.

B. Inspect overflow or discharge to ensure proper operation.

C. Provide report of maintenance and inspection information to Sarasota County Government and the Southwest Florida Water Management District at the time of WUP report.

3.3.5.3 Testing the System

The harvesting pump and filtration system should be tested regularly for proper use. If an irrigation system is used, it should be tested regularly to ensure proper operation of the float gauges, pump, timer, meter, and precipitation shut off.

3.3.5.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of a stormwater harvesting system. Maintenance responsibility must be vested in a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.3.6 References

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CHAPTER 3.4: Greenroof Stormwater Treatment Systems

3.4 GREENROOF STORMWATER TREATMENT SYSTEMS

Key Considerations	**Practice Intent:** ▪ Reduce runoff volume and treat and store stormwater at the source. **Design Criteria:** ▪ Must be located on a building roof. ▪ Treatment area must include a waterproofing layer, root barrier layer, drainage layer, (optional pollution-control layer), filter fabric, growth media layer, and vegetation with irrigation and water storage for greenroof filtrate. ▪ Recommended storage of 1 gallon for each square foot of greenroof area. **Advantage/Benefits:** ▪ Suitable for most buildings and retrofits, but typically used on flat roofs. ▪ Good for highly impervious areas with ground-level space limitations. ▪ Can meet pollution- and volume-control targets. ▪ Increases thermal efficiency of roof. ▪ Increases life of roof to 50+ years. ▪ Relatively low maintenance requirements. ▪ Can be planned as an aesthetic feature. **Disadvantages/Limitations:** ▪ Structural limitations. ▪ Initial capital costs. **Maintenance Requirements:** ▪ Inspect and repair/replace treatment area components.
Pollutant Removal Potential	**H** **Total Suspended Solids** **H** **Nutrients**—Total Phosphorous, Ortho Phosphorous, Nitrates, Ammonium **H/M** **Metals**—Cadmium, Copper, Lead, and Zinc removal **M** **Pathogens**—Coliform, Streptococci, E. Coli removal
Stormwater Management Suitability	☒ **Water Quality** ☒ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Limited use **High-Density/Ultra-Urban:** Yes **Drainage Area:** Roof coverage **Shallow Water Table:** NA **Soils:** Plant growth media must meet specified criteria.
Other Considerations:	Use of native plants is highly recommended. Must harvest filtrate to irrigate the greenroof. Other harvesting for ground-level irrigation, car washing, and graywater is possible upon adequate treatment. Standard roofing practices must be followed to ensure structural integrity as well as watertight membrane with overflow drains.

L—Low, **M**—Moderate, **H**—High

3.4.1 General

3.4.1.1 Overview and Intent

A greenroof is a roof with vegetation planted in a media on the roof. A greenroof stormwater treatment system is a vegetated roof with a cistern or dedicated water storage area. The system can be used for stormwater pollution control, volume reduction, and peak flow reduction. In addition to vegetation, a greenroof has selected growth media and pollution-control media. Water which falls on a greenroof filters through the media to the roof drainage system. The filtrate from the greenroof discharges to a cistern that stores water. The filtrate water from the cistern is used first to irrigate the greenroof and then, if there is overflow, the water may be used for irrigating ground-level landscaping. If approved with treatment, it may be used as graywater in a building. As a last option it is discharged to a pond or another stormwater treatment train. A cistern is located either above or below ground or, less frequently, within the structure or on the roof. It must; however, have sufficient capacity to store roof filtrate to irrigate the greenroof.

A greenroof stormwater treatment system is ideal for just about any application where there is a suitable rooftop area and structural capacity. Sloped roofs can also be made as a greenroof, but the application to sloped areas requires more detailed designs. Greenroofs can; however, be designed to be lightweight, thus making them viable for retrofits.

A greenroof stormwater treatment system intercepts rainfall where it is deposited and filters and holds the filtrate water, thus reducing roof runoff. The filtrate from rainfall and irrigation that is not held in the greenroof media is released to water storage before discharge. Drainage must be provided for excess water so there is minimal water storage in the media. A cistern or other water-storage device is used for irrigation to keep the plants on the greenroof alive and, if needed, for ground-level landscaping. The greenroof can be used on sloped roofs as well as "flat" roofs and consists of, first, a waterproof layer, typically a Polyvinyl Chloride (PVC) or Thermal Plastic Olefin (TPO) membrane as these are inherent root barriers. Next, a protection layer, a drainage layer, a pollution-control layer, separation fabric, greenroof growth media, a cistern or water storage, a drip irrigation system, and plants are added. The greenroof filtrate contributes to the cistern as water not retained in the greenroof. The cistern only contributes to discharge when it is full. To minimize system overflows the cistern can be sized larger. Overflows should be discharged to other on-site stormwater controls or other pervious areas.

A greenroof is typically classified into two types, an active greenroof or a passive greenroof. An active greenroof is one in which public access is allowed. A passive greenroof is one in which no public access is allowed. Passive greenroofs are usually shallow, with a typical depth of 4 inches of growth media and pollution-control media, while active greenroofs are typically greater than 4 inches in depth. Active greenroofs often require more design detail, safety requirements, insurance, structural considerations (additional dead load due to the additional depth and live load due to people using it), and maintenance.

There are numerous design applications for greenroof stormwater treatment systems, including being used on everything from single-family residential homes to high-density “ultra-urban” environments. Figures 3.4-1 through 3.4-3 illustrate examples of greenroof stormwater treatment systems, and Figures 3.4-4 and 3.4-5 are typical sections.

Figure 3.4-1 Example Greenroof

Figure 3.4-2 Example of Above-Ground Industrial Cistern Storage

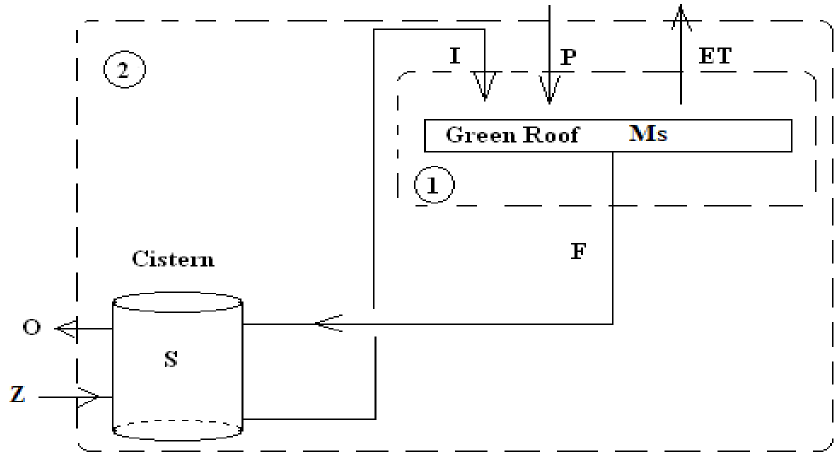

Figure 3.4-3 Greenroof Stormwater Treatment System Schematic

Legend:

I= Irrigation, P= Rain, ET = Evapotranspiration, F= Filtrate, O= Overflow, Z= Make-up, S=Storage

1= Mass Balance for the greenroof, 2=Mass Balance for the Greenroof and Cistern

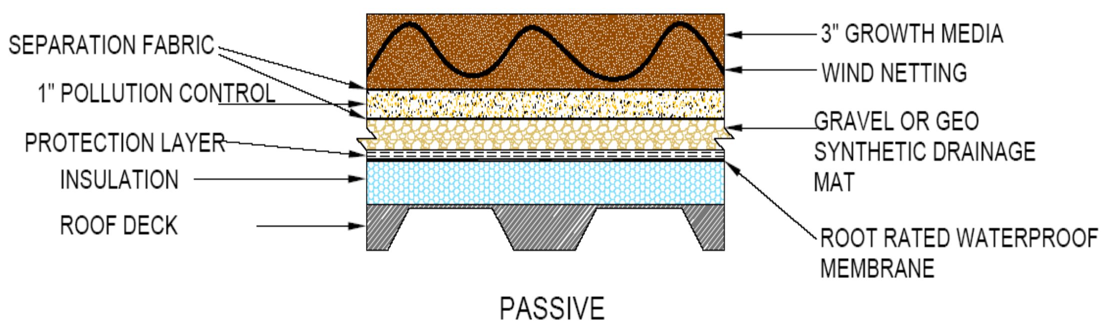

Figure 3.4-4 Typical Passive Greenroof Section

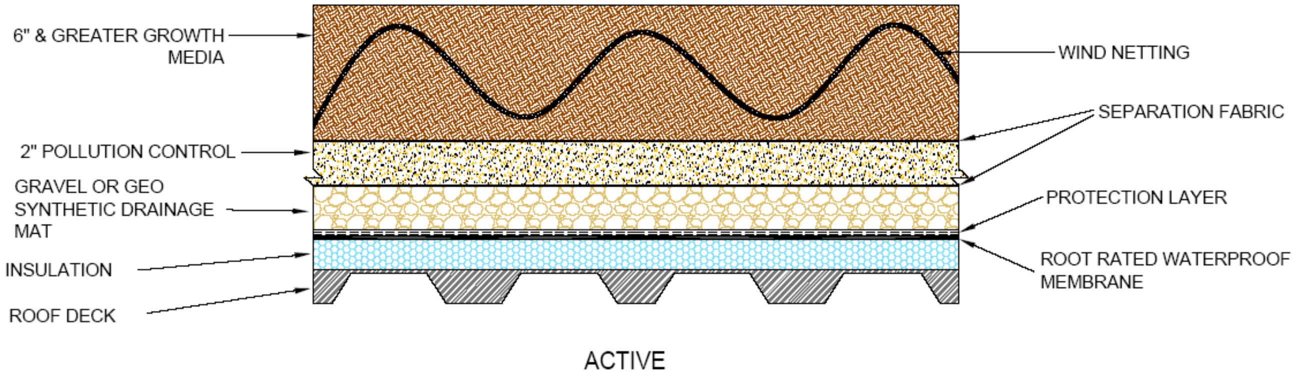

Figure 3.4-5 Typical Active Greenroof Section

3.4.1.2 Applicability

Water Quantity Control

A greenroof stormwater treatment system is designed primarily for stormwater volume and water quality control, i.e. the reduction of stormwater pollutants. However, greenroof stormwater treatment systems also provide peak flow control. A greenroof will attenuate the hydrograph before the cistern and the attenuation into the collection system is controlled by the outlet conditions of the cistern. Greenroofs can reduce peak flow and increase the time of concentration (see www.stormwater.ucf.edu), thus reducing the amount of stormwater generated from the surface while increasing the time for the peak flow to occur. The yearly volume reduction for a specific size of cistern is estimated from Figure 3.4-6.

Water Quality Control

To achieve a targeted average annual load reduction, a cistern must be used. With a cistern, mass reduction in pollutants, including nutrients, can be expected over the lifetime of the greenroof system. The concentration of total nitrogen and total phosphorus is, on the average, less than the concentration from a conventional roof. In addition, it is important to have a media mix which is low in organics (less than 10%) and able to support plant growth. For example, when a cistern is designed for 1.6 inches of water over the greenroof area, a mass reduction of at least 75% on an average yearly basis can be achieved (Figure 3.4-6). If the cistern size is increased to 3.5 inches of water over the greenroof area, 85% effectiveness is obtained.

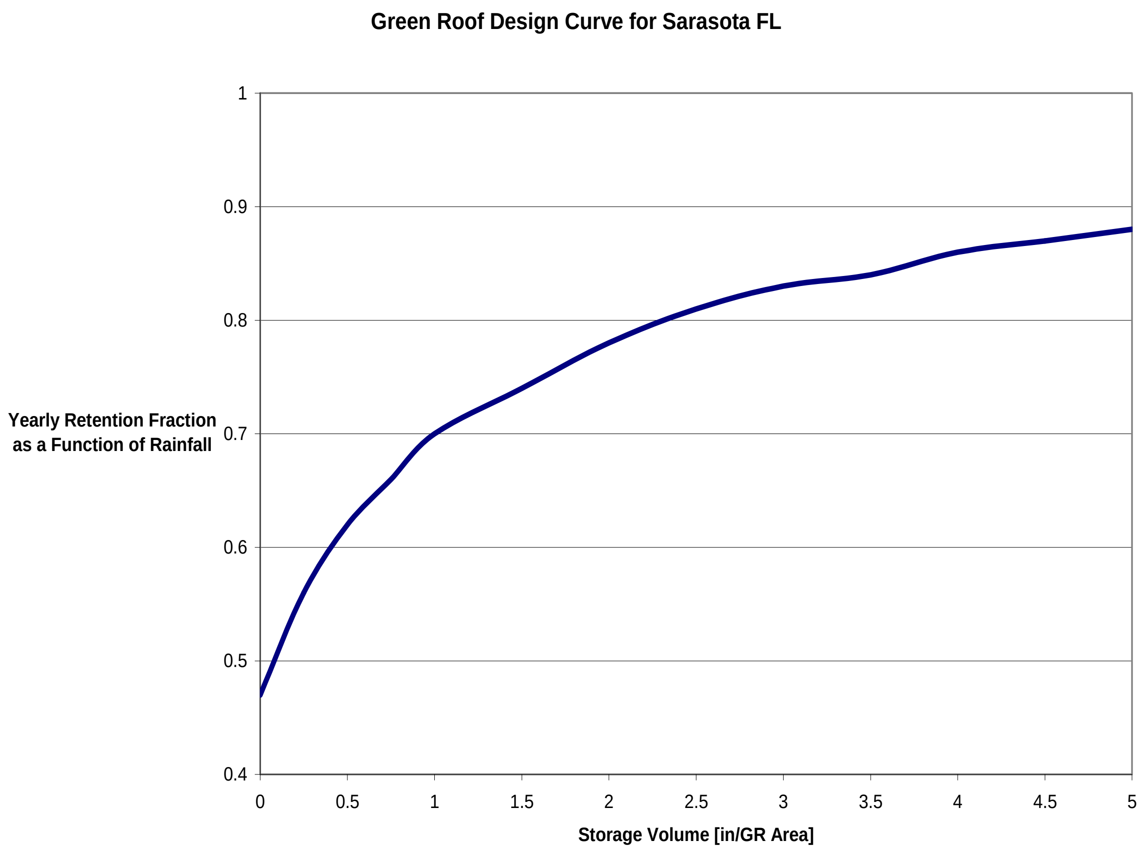

Figure 3.4-6 Greenroof Stormwater Treatment System Cistern Design Curve

Where: GR= greenroof area. Assumes an irrigation schedule of no more than 1.5 inches per week during April through September, no more than 0.75-inch per week during October and November, and no more than 0.25-inch per week in December through March. The schedule also assumes no irrigation when rainfall occurs at the irrigation rate in the previous day. The irrigation cycle is a maximum of two times per week. This schedule must be maintained.

General Feasibility

A greenroof is usually installed on a flat surface with minimum slope for drainage but can also be installed on a sloped surface using specific construction methods. Greenroofs are found in commercial and industrial areas or on homes in residential subdivisions.

Physical Constraints

When evaluating the appropriateness of a greenroof, an applicant should consider some of the physical constraints associated with this type of roof. Some of these physical constraints include:

A. Space Required – For a cistern and a pond.

B. Roof Slope – At minimum 2% slope (1/4 inch per foot).

C. Building Height – Will affect plant selection.

D. Building sun exposure – Will affect plant selection.

E. Makeup water source – Stormwater and graywater (including air conditioner condensate) are added as a first choice.

F. Parapets are usually designed and provide wind protection; edge restraints for the media can be used and fastened to the roof membrane, usually with hurricane glue.

3.4.2 Design Considerations and Requirements

The following criteria are considered **minimum** standards for the design of a greenroof stormwater treatment system in Sarasota County. Applicants should consult with SWFWMD to determine whether there are any variations of these criteria or if they must follow additional standards.

3.4.2.1 Design Considerations and Requirements

A greenroof with a continuous or loose-laid layer is preferred over one with trays or panels for plants. Each layer of the greenroof should follow specifications for design to achieve pollution and volume controls while maintaining safety. The following are the system components and requirements for design:

A. Waterproof Membrane-must be incorporated to protect the structure from moisture damage

   1. Several options are available such as a PVC or TPO waterproof membrane and should be used over a sloped (at least 2%) roof deck.
   2. The membrane must be root-barrier rated and cannot contain metals.

B. Drainage Layer-used so that no standing water is present

   1. The drainage layer should either be gravel covered with a non-woven separation fabric or a geo-synthetic drainage layer to prevent clogging.
   2. The drainage layer must support the wet weight of the greenroof layers.

C. Pollution-control layer-optional layer used to adsorb nutrients

1. A material that removes nitrogen and phosphorus through sorption or other means.
2. At least 1 inch thick on passive greenroofs and at least 2 inches thick on active greenroofs.
3. No more than 15% particles, by mass, passing sieve # 200 (0.075 mm).
4. Permeability greater than or equal to 1.5 inches per hour.
5. Water-holding capacity of at least 30%.
6. No more than 10% organics by volume.
7. Typically, media has unit weight of 45 pounds per cubic foot or less when dry and 65 pounds per cubic foot when wet.

D. Separation fabric

1. A non-woven geo-synthetic fabric should be used for separation.
2. The separation fabric should not allow more than 7% of the media to pass through it.

E. Greenroof growth media recommendations

1. The 3 inch growth media is the main support media for vegetation growth.
2. No more than 15% of the material used for the growth media should pass through Sieve Number 200 (0.075mm).
3. The media should be over 50% mineral and should contain no shale or other materials dark in color.
4. The media should have a water holding capacity greater than 30%.
5. The media should have a water permeability of at least 1.5 inches per hour.
6. The organic content of the media should be no more than 10% by volume.
7. Wind netting must be mixed with the upper 1-inch layer for wind protection or a parapet should be used.

F. Catchment area

1. Roof drain pipes or system must be directed to a cistern.
2. Either interior drains or scupper drains used as overflow drains.
3. Drains protected and covered with a removable lid to prevent media or plant matter from clogging drains. Usually an edge restraint is placed at least 1 foot from the drain.

G. Drip irrigation system

1. Irrigation water shall be supplied from a non-potable source such as a cistern or water storage area first.

2. Drip irrigation should be placed as close as possible to the plants, usually with one foot on-center spacing.
3. Irrigation rates vary with the season but are less than 1.5 inches per week.
4. A rain shut-off sensor or soil moisture sensors are neededfor irrigation shut off.
5. Backflow prevention devices on any auxiliary back-up source must be provided and requires an annual inspection.

H. Cistern/Water storage

1. The cistern stores greenroof filtrate and if needed air conditioner condensate for irrigation.
2. The cistern can be either below or above ground. If above-ground storage is used, the cistern material must be UV stable.
3. The cistern can also collect rainwater generated from other roofs on the site provided the other roof areas do not have chemicals that will damage the plants. These sources must be metered.
4. The installation must follow the Florida Building Code or its successors.
5. Prevention of unintentional entry from humans or vermin must be part of the design. Also inspection and cleaning access with venting and appropriate safety signs must be provided.
6. The irrigation return line must be metered and must have a filter that meets the irrigation system filtration requirements.
7. An overflow drain is required and must be sized to accommodate the 100-year/24-hour design flow.
8. The cistern size (dedicated water volume) can be determined using Figure 3.4-6; however, the water demand should be determined first.
9. An auxiliary back-up water supply must be provided; stormwater and graywater (including air conditioner condensate) are preferred, but others should be considered. If reclaimed water is used, it must be fully used during the intended irrigation cycle and proper signage added.

I. Vegetation layer

1. Use of native or Florida-friendly plants accustomed to high temperatures is encouraged.
2. Local nurseries should be consulted for native and Florida-friendly plant recommendations.
3. On passive roofs, low-profile plants are preferred. There must be a plan for securing larger plants and trees, if used, against high winds.
4. Amount of shading from near-by areas should be considered in the plant selection.

J. Available Standards

National standards may be used as an aid when designing greenroof systems. These standards do not replace or supersede the Sarasota County requirements for greenroof stormwater systems:

1. ASTM Standard E2396, 2005, Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems.
2. ASTM Standard E2398, 2005, Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems.
3. ASTM Standard E2397, 2005, Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems.
4. ASTM Standard E2400, 2006, Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.
5. ASTM Standard E2399, 2005, Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems.
6. ASTM Standard D5957, 2005, Standard Guide for Flood Testing Horizontal Waterproofing Installations.

3.4.2.2 Peak Discharge Requirements

If used as a stand-alone system, the greenroof stormwater treatment system overflow should not exceed the predevelopment runoff volume. A greenroof can be used in series with other stormwater systems and the peak attenuation can be developed. In some cases the overflow from the cistern of water storage area itself may be sufficient to meet peak discharge requirements.

If no cistern is used and the system overflow is directly connected to a stormwater pond or other flood-control structures, the greenroof area is to be treated as a directly connected impervious surface area. For flood control, a 4-inch-deep greenroof is treated as having a Curve Number (CN) = 96 (storage = 0.40 inch) and an 8-inch-deep roof as having a CN = 95 (storage = 0.50 inch).

3.4.2.3 Maintenance Considerations

Adequate access must be provided for all greenroof stormwater treatment system facilities for inspection, maintenance, and plant upkeep, including appropriate equipment. A source of water must be provided at the roof in case of malfunctioning irrigation or other needs.

3.4.2.4 Safety Considerations

Safety concerns that are recommended for all greenroof designs include the following:

A. Access to the roof should be controlled. The degree of control depends on the type of activities that will be carried out on the roof.

B. Safety features may include railings for active greenroofs if the parapet does not meet local building codes for public access.

C. All roofs should have a limited-access feature and policy in place.

D. All pipes that transport water for harvesting should be labeled as ‘Non-potable. Do not drink.’

3.4.2.5 Additional Design Considerations

A greenroof stormwater treatment system design may include the following:

A. Lighting and electrical outlets.

B. Another water source at the roof as backup irrigation and in case of fire.

C. Walking paths for maintaining roof mechanical equipment.

D. A leak-detection system for the cistern.

3.4.3 Cistern Design Procedure

For a greenroof to earn pollution-control or stormwater credits, the average annual mass reduction in pollutants provided by the cistern must be demonstrated. The cistern size shall be based on water demand and the source water reliability. A procedure for adequately sizing the cistern is provided below:

- *Step 1* - Computing Predevelopment Runoff Volume

  The rainfall runoff pattern for the Sarasota area is in Rainfall Cluster 4. The predevelopment annual runoff fraction is determined from published charts. This will be matched to the post condition. The cistern should be sized to contain at least 1.6 inches of runoff over the greenroof area.

- *Step 2* - Computing Post-Condition Runoff Volume

  The post-condition annual runoff coefficient (C=0.823) assumes that the greenroof is 100% directly connected (Appendix A, Table A-1). The annual runoff volume is the product of the annual rainfall (Appendix A, Figure A-1) and the coefficient.

- *Step 3* - Cistern Sizing Requirements and Example

  Cistern or other water-storage devices used in greenroof stormwater treatment systems are typically sized to handle the anticipated water demand and to capture 80% or more of the average annual rainfall by using design curves developed using models. The curves provided in this section were created by the Continuous Stormwater Treatment Outflow Reduction Model (CSTORM model), developed by the University of Central Florida (see Figure 3.4-6). This model is not available to the public.

  Example Calculations:

  A 20,000-square-foot active greenroof is planned on a commercial building in the Sarasota area. What size cistern is needed to control the runoff to achieve predevelopment equal to post-development mass of runoff and pollution? The predevelopment site has a CN value of 80 with no directly connected impervious area (0%).

  Solution: The mean annual runoff coefficient for the predevelopment condition is 0.130 (see Appendix A, Table A-1). The post-condition annual runoff coefficient is 0.823 (also see Table A-1). Thus, assuming that the concentration of the greenroof system is equal to that of the predevelopment condition, the mass percent removal is calculated as (0.823 – 0.130)/.823 = approximately 85%. Thus from Figure 3.4-6, the cistern size is 3.5 inches over the greenroof area, or 5,833 cubic feet. Annual runoff can be calculated by multiplying the annual runoff coefficient by the annual rainfall (see Figure A-1 in Appendix A for annual rainfall). Nutrient concentrations are assumed to be less than that from the predevelopment condition.

- *Step 4* - Confirm Local Design Criteria and Applicability

  Check with local officials and other agencies to determine if any additional restrictions and/or surface water or watershed requirements may apply.

- *Step 5* - Compute Peak Discharge

  The peak rate of discharge is calculated knowing the cistern volume discharge relationship, which is determined from the outflow discharge structure (weir, orifice, or the like). The peak discharge is then compared to the predevelopment discharge for design storm conditions.

3.4.4 Construction

A roofing construction company with experience in greenroof installations should be chosen. Construction trades should be coordinated to ensure the operation of the greenroof system for stormwater management as well as for structural integrity. The following items should be considered before construction begins:

A. The support structure for a greenroof must provide for the wet weight of the media. The media weight depends on the media mix and the depth of the media. Wet media weight is typically less than 65 pounds/cubic foot.

B. All of the media used should be free of local plant seeds; thus, covering the media at the job site is necessary if there is a delay in loading the roof.

C. The minimum slope of the roof structure for drainage is 2%. Provisions for overflow must also be included in the design using interior drains or scuppers.

D. The roof water protection membrane must be a certified root barrier or a root barrier must be added. The root barrier must not be made of metal or metal composites.

E. After the water protection membrane is completed, a leak test must be performed.

F. The cistern or dedicated pond must be installed before the greenroof plants are added so that a source of irrigation water is available. If not, an alternative water source must be available.

G. For back-up watering and emergency purposes, a water “bibb” is typically available on or near the roof line.

H. Provision for power is also frequently available for lighting effects or repair services.

I. Access to any mechanical equipment must be planned. Vertical and horizontal distances between the mechanical equipment and the greenroof are needed to ensure proper operation of the mechanical equipment.

J. If the roof is a passive one, access to workers and others must be strictly limited.

3.4.5 Operation and Maintenance

The operation and maintenance entity is required to provide for the inspection of the total surface water management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections shall be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter.

3.4.5.1 Recommended Maintenance

The maintenance record or log of activities should include data on the following:

A. Irrigation volume measured using a flow meter.

B. Cistern overflow volume.

C. Observations of the irrigation system and replacement of parts.

D. Removal of nuisance species or invasive exotics.

E. Removal and replacement of dead, dying, or damaged plants.

F. Maintenance of roof mechanical equipment.

G. Fertilizer, pesticides, and compost added consistent with ground-surface-level use.

3.4.5.2 Suggested Inspection Items

The following minimum inspection items should be carried out and documented in the maintenance record at least every 2 years:

A. Inspect drains for clogging. Remove any plants growing in the drain area as well as any debris.

B. Inspect the irrigation system for clogging. Replace clogged sections.

C. Inspect overflow devices to ensure proper operation.

D. Inspect membrane along parapet walls, drains, and all protrusions according to the manufacture's recommendations.

E. Replace diseased and dying plants. Use a different plant species in that location if the problem persists.

3.4.5.3 Testing

The waterproof membrane must be tested using either a flood test or equivalent before the media is installed on the greenroof. The irrigation system should be tested annually to ensure proper operation of the float switch, pump, timer, meter, and precipitation shut off. The owner may want to record any leaks in the roof and maintainall testing records.

3.4.5.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of greenroof stormwater treatment systems. Maintenance responsibility for a greenroof stormwater treatment system must be vested with a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.4.6 References

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SECTION 3.5: Rainwater Harvesting

3.5 RAINWATER HARVESTING

Key Considerations	**Practice Intent:** Intended as a component of a treatment train that only addresses impact of roof runoff on the stormwater system. Roof runoff is collected before it contacts the ground, thereby preventing rainwater from becoming stormwater. Using rainwater within the site footprint reduces the runoff volume. **Design Criteria:** Calculate roof area; determine use for harvested water (irrigation, graywater, potable); and determine harvesting rate, harvesting volume, irrigation method, and equipment. Determine additional requirements for graywater and/or potable use. **Advantage/Benefits:** ▪ Can meet volume-control targets. ▪ Can be used to replace reliance on more costly potable water. ▪ May have a low maintenance requirement. ▪ Can be planned as an aesthetic feature. ▪ Can use purple pipe but cannot mix harvested water with reclaimed water at the same time. **Disadvantages/Limitations:** ▪ May require a pump that has to be monitored using a flow meter or flow totalizer. **Maintenance Requirements:** ▪ Inspect and maintain cistern, first flush diverter, screen, pump, and irrigation or other conveyance components.
Pollutant Removal Potential	**H** **Total Suspended Solids** **H** **Nutrients**—Total Phosphorous, Nitrate **L** **Metals** **L/H** **Pathogens**—Coliform, Streptococci, E. Coli removal with systems that include disinfection
Stormwater Management Suitability	☒ **Water Quality** ☐ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Yes: irrigation and graywater **High-Density/Ultra-Urban:** Yes: irrigation and graywater **Drainage Area:** Roof area collected by gutters **Shallow Water Table:** NA **Soils:** NA
Other Considerations:	Connecting a harvested rainwater system to a distribution system inside of an occupied space requires approval by the Sarasota County Health Department. Example of these types of systems include using harvested rainwater for toilet flushing, clothes washing, irrigation of indoor planters, hose bibs, car washing, and potable water.

L—Low, **M**—Moderate, **H**—High

3.5.1 General

3.5.1.1 Overview and Intent

Rain is a free source of relatively clean, soft water. As rain falls onto surfaces such as concrete, pavement, and grass it contacts more contaminants than it would from dry fallout on a roof. Harvesting rainwater from roof runoff is an easy, inexpensive way to capture water before it has contacted many potential contaminants. There are four types of rainwater harvesting systems:

- Small residential systems that store rainwater in rain barrels for supplemental irrigation.
- Large residential or commercial systems that store rainwater in a cistern for irrigation, vehicle washing, dust control, or other outdoor, non-potable uses.
- Large residential or commercial systems that store rainwater in a cistern as a source of indoor graywater uses such as toilet flushing, urinal flushing, Heating Ventilating and Air Conditioning (HVAC) make-up water, laundry wash water, and outdoor non-potable uses.
- Residential or commercial systems that store rainwater in a cistern as a source of potable water.

Type 1 Non-potable Residential System with a Rain Barrel

The first type of system is a small residential system which stores rainwater in rain barrels. These systems allow homeowners to retrofit their homes to reduce runoff and the amount of potable water consumed for irrigation. Many sources of information on designing and installing these systems are available on the internet
http://www.scgov.net/EnvironmentalServices/Water/Rainbarrel.asp
(http://www.swfwmd.state.fl.us/conservation/rainbarrel/ or
http://sarasota.extension.ufl.edu/Hort/Pubs/Rainbarrel.shtml) and at home centers. Although Sarasota County encourages the use of rain barrels by homeowners; however, they would not qualify for stormwater credit so they are not discussed further in this manual.

Figure 3.5-1 Rainwater Harvesting with a Rain Barrel

Type 2 Non-potable System for Outdoor Use with a Cistern

The second type of system is a large commercial or residential system that uses a cistern to store water for irrigation and/or other outdoor uses. In these systems:

- Rainwater is collected by gutters and scuppers and routed through downspouts to a cistern.
- The downspouts are equipped with a device to divert the first flush of water away from the cistern and to screen out large material such as leaves.
- Cisterns are larger than 80 gallons and may provide aboveground or underground storage. If the cistern is underground, it must be constrained against buoyant forces.
- The irrigation system will likely require additional filtration and screening to prevent valves and spray heads from clogging.
- The harvested rainwater will require a pumping system to distribute the water.
- The components for this type of system are shown in Figure 3.5-2.

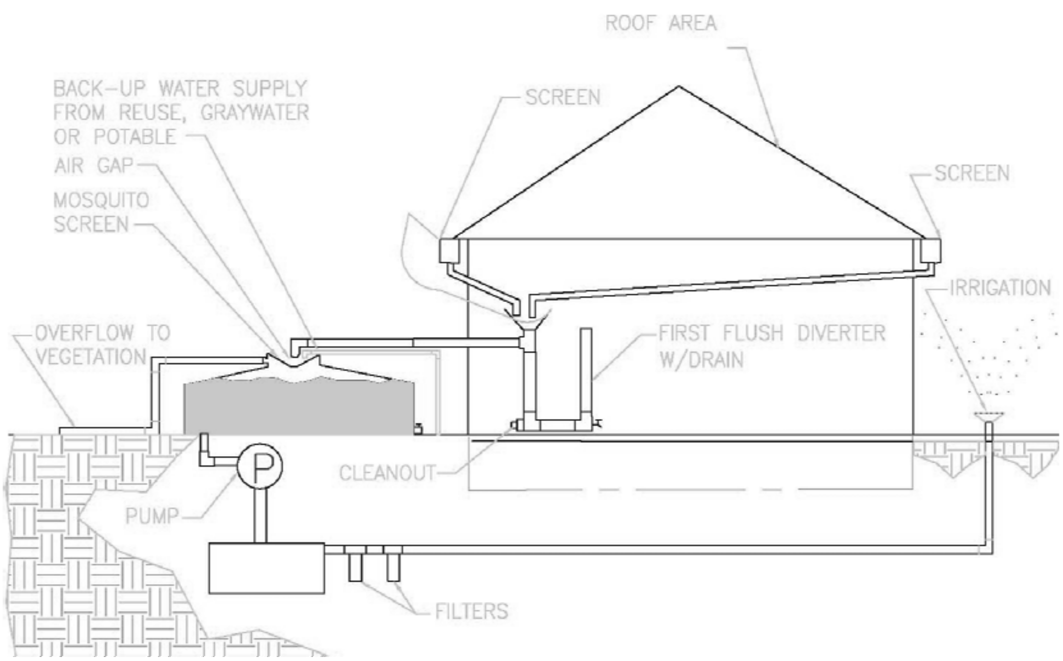

Figure 3.5-2 Rainwater Harvesting for Irrigation and For Outdoor Use

Type 3 Non-potable System for Indoor and Outdoor Use with a Cistern

The third type of system is a large residential or commercial system that stores rainwater in a cistern for indoor uses such as toilet flushing, urinal flushing, HVAC make-up water, laundry wash water, and other outdoor uses. In these systems:

- Rainwater is collected by gutters and scuppers and routed through downspouts to a cistern.
- The downspouts are equipped with a device to divert the first flush of water away from the cistern and to screen out large material such as leaves.
- Cisterns are larger than 80 gallons and may provide aboveground or underground storage. If the cistern is underground, it must be constrained against buoyant forces.
- The harvested rainwater will require a pumping system to distribute the water.
- Indoor graywater (flushing and laundry) systems require pre-filtering and fine filtering to between 5 and 20 microns.

This type of system has a potential for inadvertent human contact or consumption; therefore, the system has additional requirements from the Sarasota County Health Department. The components for this type of system are shown in Figure 3.5-3.

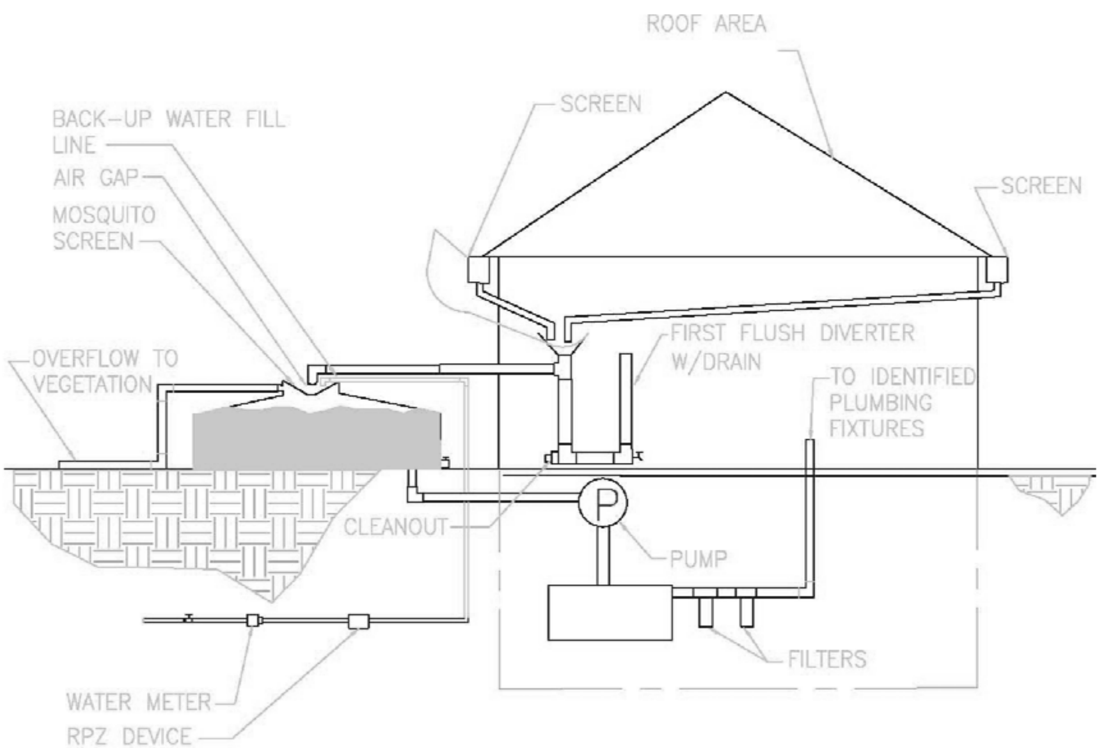

Figure 3.5-3 Rainwater Harvesting for Graywater Supply and Outdoor Use

Type 4 Potable Use with a Cistern

The fourth type of system is a residential or commercial system that stores rainwater in a cistern as a source of potable water. This type of system is designed for human consumption; therefore, the system has additional design, operating, and permitting requirements from the Sarasota County Health Department and Sarasota County Development Services.

3.5.1.2 Applicability

A Rainwater Harvesting System (RHS) is primarily designed to store and supply rainwater for use in lieu of high-quality potable water. The cistern storage volume provides an ancillary benefit in regards to stormwater.

Water Quantity Control

A RHS provides a yearly volume reduction that depends on the size of the cistern and the use of the rainwater. However, a rainwater harvesting system does not provide any peak attenuation or flood control as required by Sarasota County and SWFWMD.

Water Quality Control

Rain is a relatively clean source of water. However, the initial runoff from a roof can contain dust, fecal material, and particulate matter that accumulates on the roof. This initial runoff is diverted from the cistern by the first-flush diverter. Rainfall is a source of nitrogen from atmospheric deposition. Harvesting rainfall results in a reduction in the nitrogen load as well as other pollutants.

To achieve a desired average annual load reduction, the cistern must be designed with the target annual average volume reduction, harvesting rate, and water use rate, in mind.

General Feasibility

Rainwater Harvesting Systems are found in commercial, residential, and industrial areas.

Physical Constraints

The roof must have gutters or drains with the appropriate screens to collect the rainwater. The site must have adequate space for a cistern and may need to be anchored to a structure. There must be a use for the harvested rainwater.

A makeup water source may be required for periods of low rainfall. Stormwater and graywater (including air conditioner condensate), are the first choices for irrigation systems. Make-up water within an occupied space will likely be potable water. Potable water supplies must be separated using a backflow prevention device. An air gap is preferred.

3.5.2 Design Considerations and Requirements

Stormwater control calculations typically demonstrate one of three target level reductions: 1) matching post- to pre- runoff volume, 2) matching post-pollutant loads to pre-pollutant loads, or 3) meeting a specified percent reduction. On a typical site the roof is a small portion of the site. Therefore, the preferred method of calculation is to demonstrate that the rainwater harvesting system meets a standard percent reduction.

The rainwater harvesting storage volume may be determined by calculating the volume of water necessary to sustain the desired water use: irrigation, graywater, or potable water supply. The applicant will size the cistern to satisfy the water-use demand. Using the calculated cistern volume, the applicant may then calculate the harvesting rate normalized to the roof catchment area. This volume is used to determine a runoff-capture efficiency using the curves provided in Figure 3.5-4 and Figure 3.3-1. In cases where the design is constrained by the area available for storage and/or the water use rate, the applicant; may work within those constraints to determine the water quality benefits using the same figures. It should be noted that Figure 3.5-4 is a Rate Efficiency Volume (REV) curve for a constant daily water demand in Sarasota County, while Figure 3.3-1 is a REV curve for an irrigation demand. If the daily demand is expected to vary by more than 10%, either the lowest expected daily demand must be used on Figure 3.5-5 or the average annual reduction in runoff from the roof must be demonstrated using a continuous simulation based on at least 20 years of rainfall data.

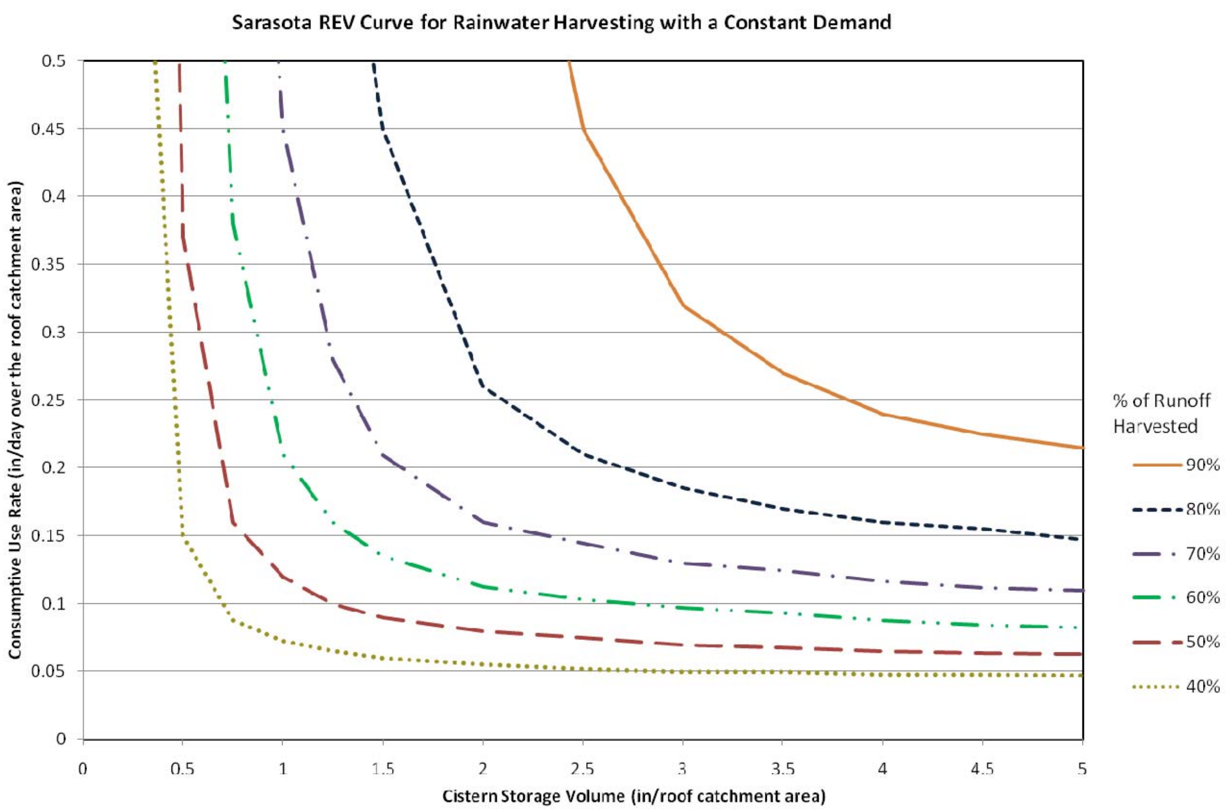

Figure 3.5-4 REV Curves for Rainwater Harvesting in Sarasota, FL with a Constant Daily Demand

The following criteria are considered **minimum** standards for the design of a rainwater harvesting system for stormwater credit in Sarasota County. The applicant should consult with the SWFWMD, the Florida Building Code for Plumbing (Florida, 2007), or its successors, the Sarasota County Health Department and determine if there are any variations to these criteria or additional standards that must be followed.

3.5.2.1 Catchment System

A. The gutters, downspouts, drains, and pipes for the collection system must be directed to a cistern.

B. Gutters and drains must be protected and covered with a removable screen to prevent debris from clogging drains.

C. For every inch of rain that falls on a roof area of 1,000 square feet, approximately 600 gallons of rainwater may be collected. One inch of rain falling on a square foot surface yields approximately 0.6 gallons of water. As a result of water loss in the system, it is estimated that about 75% of the harvested rainfall can be captured or 0.46 gallons.

D. The first flush of rainwater, equivalent to the first gallon of runoff per 100 square feet of roof area, must be discarded after each rain event to ensure only the cleanest water is stored in the cistern. This is accomplished by installing a first-flush diverter before the cistern, typically within the downspout. The diverted rainwater is routed to a vegetated area. Several manufacturers offer proprietary first-flush diverters; some of these diverters use a vortex to separate debris while reducing the need for maintenance. A schematic of a simple first-flush diverter is shown in Figure 3.5-5.

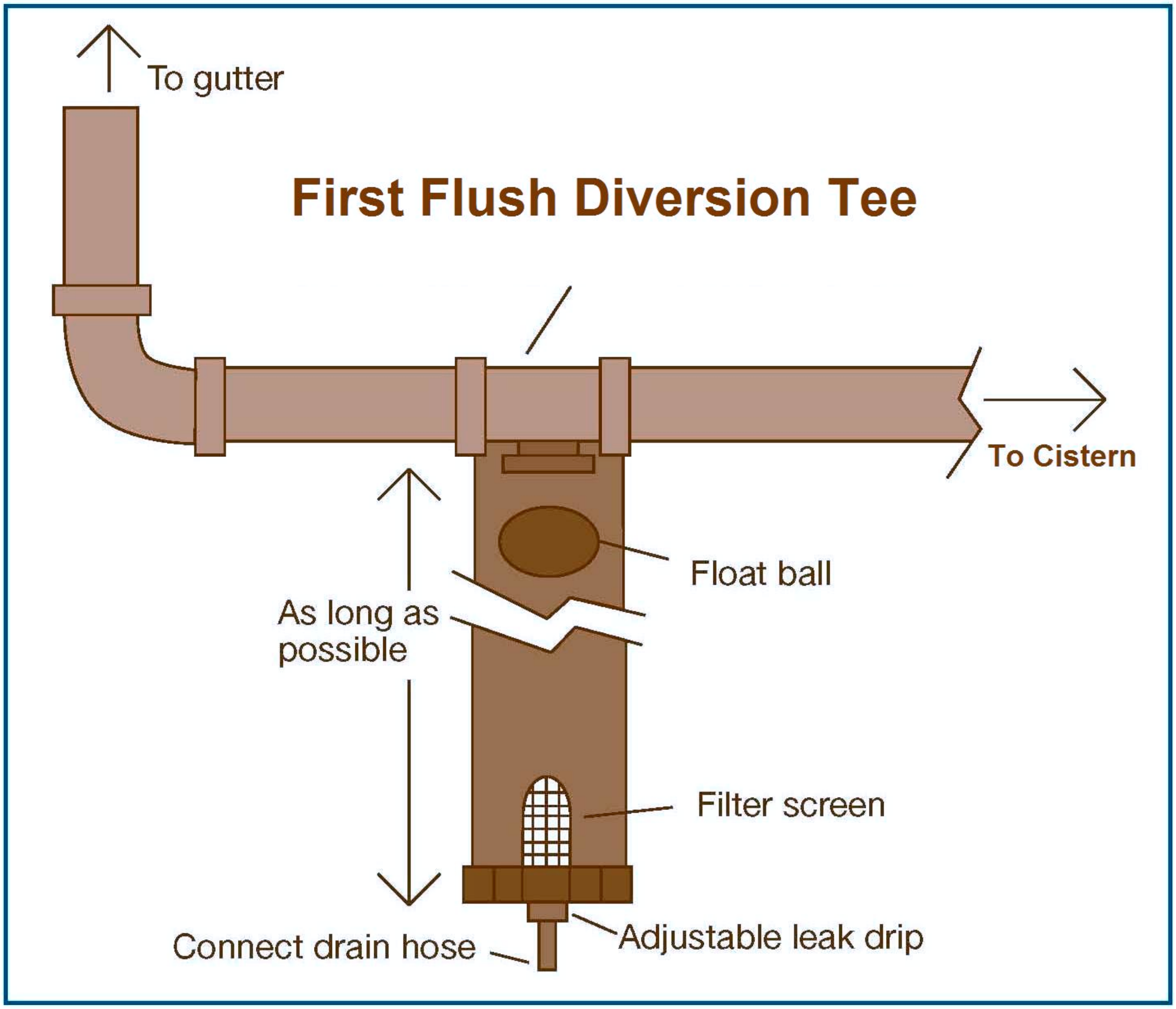

Figure 3.5-5 First-Flush Diverter (Oregon, 2009)

3.5.2.2 Filtering and Screening

A. All RHSs require screens to prevent large debris from entering the cistern.

B. Irrigation systems require pre-filtering to remove particles that may affect valve and sprinkler operation. The filtering system should be designed in accordance with the requirements of the irrigation system (see Figure 3.5-2).

C. Indoor graywater (flushing and laundry) systems require pre-filtering and fine filtering to between 5 and 20 microns (see Figure 3.5-3).

3.5.2.3 Cistern

A. The cistern may be installed below or above ground. If aboveground storage is used, it must be UV stable. The cistern must inhibit algal growth without biocides or toxic substances. This criterion may be met simply with an opaque tank.

B. The installation must follow the Florida Building Code for Plumbing and the Florida Building Code for Electrical.

C. Prevention of unintentional entry by humans or vermin must be part of the design. Also inspection and cleaning access with venting and appropriate safety signs must be provided.

D. The water supply line (e.g., irrigation line or graywater line) must be metered and have a filter.

E. An overflow drain is required. It must be sized to accommodate the 100-year/ 24-hour design storm flows. The appropriate downstream erosion controls must be made.

F. The cistern size (dedicated water volume) must be determined based on the water use.

G. An auxiliary back-up water supply must be provided; graywater (including air conditioner condensate) is preferred for irrigation systems, but others should be considered. If reclaimed water is used, it must be fully used during the intended irrigation cycle and proper signage should be added.

3.5.2.4 Irrigation system

A. Irrigation water is supplied from a cistern.

B. Irrigation rates and timing must comply with current watering restrictions.

C. Rain sensors or soil moisture sensors for irrigation shut off must be provided.

D. Watering restrictions are applicable to irrigations systems supplied with rainwater.

E. Backflow prevention devices on any auxiliary back-up source must be provided.

3.5.2.5 Graywater system

A. Asphalt shingles and cedar shakes may not be used as a roofing material for the catchment area for a graywater or potable water system. These materials can leach potentially toxic materials such as copper oxide and petroleum products. (Texas, 2007)

B. Harvested rainwater is supplied from a cistern for graywater use within an occupied space.

C. Filters are required between the pump and the connection to the plumbing system to provide pre-filtering and fine filtering to between 5 and 20 microns.

D. Backflow prevention devices on any auxiliary back-up source must be provided.

E. All RHSs connecting to a plumbing system within an occupied space must be approved by the Sarasota County Health Department and Sarasota County Development Services. These systems may have additional design, and maintenance requirements.

3.5.2.6 Discharge Requirements

A RHS is expected to have two discharges: the water diverted from the first flush and the cistern overflow. The appropriate erosion control must be made downstream of both discharges. Where possible, the first-flush water must be discharged to a landscaped area.

3.5.2.7 Maintenance Considerations

Adequate access must be provided for harvesting systems and facilities for inspection, maintenance, and pump upkeep, including all appropriate valves, spray heads, and piping. A back-up source of water must be provided to ensure available harvesting water. Possible sources are graywater, air conditioner condensate, or reclaimed wastewater. The reclaimed wastewater is not mixed in the storage area but is used directly in the distribution line.

Adequate access must be provided for all RHS facilities for inspection and maintenance.

3.5.2.8 Safety Considerations

Safety considerations to be addressed for all rainwater harvesting designs include but are not limited to the following:

A. Access to the pump and cistern must be controlled.

B. Safety features may include fencing and signage.

C. Depending on the end use, electrical back-up when power is down is recommended as part of emergency operations.

D. All pipes that transport water for harvesting must be labeled as ‘Non-potable. Do not drink.’ unless the system is approved by the Sarasota County Health Department for potable use.

E. Large cisterns and vaults may require entry for maintenance and inspection. These systems must provide appropriate safety equipment for a confined space.

F. The RHS must be separated from the potable water supply with a backflow prevention device, preferably consisting of an air gap.

3.5.2.9 Additional Design Considerations

A RHS may include the following:

A. Lighting and electrical outlets.

B. Signage with education and safety language.

C. A leak detection system for the cistern.

3.5.2.10 Additional Permitting Considerations

A. The rainwater harvesting system may require a SWFWMD water use permit.

B. The rainwater harvesting system may require a permit from the Sarasota County Health Department.

C. The rainwater harvesting system will require a permit from the Sarasota County Development Services to include electrical, plumbing, and structure anchoring.

3.5.3 Rainwater Harvesting Example Calculation

The goal of a rainwater harvesting system is typically to collect and use rainwater to offset consumption of potable water; however, harvesting rainwater also has an ancillary benefit of reducing stormwater loading. The sample calculation shown provides an example highlighting two methods of sizing a rainwater harvesting cistern based on water demand, average monthly rainfall, and size of catchment area. Average monthly rainfall is provided in Table 3.5-1. Once the cistern size is determined, it is possible to calculate the amount of rainwater diverted from the stormwater system. This diversion may be quantified as a percent reduction in runoff volume and used as part of a stormwater BMP treatment train.

Table 3.5-1 Average Monthly Rainfall Totals for Venice, Florida (Inches)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2.6	2.4	3.2	2.3	2.6	7.1	6.9	7.9	7.4	3.4	1.9	2.1

Annual average 49.8/12 = 4.15 inches

Consider the following two examples to help understand calculation procedures:

3.5.3.1 Example: Commercial Property

A commercial building is planned in the Sarasota area. The preliminary site plan has two 20000 square foot buildings on a 5 acre site. With the desired site layout of the buildings and the associated parking area the applicant determines that there is .8 acres of pervious area that will be landscaped or grass. Each of the buildings is expected to have 40 FTE (full-time equivalents). The applicant has decided to design the cistern system to collect the runoff from one of the 20,000 square foot buildings.

- *Step 1* – Calculate the water demand

    - *Step 1a* – Calculate potential irrigation water demand

      Calculating irrigation demand depends on several factors, including the soil and plant type. Sarasota County encourages using native landscaping with a low water demand. For simplicity, we are assuming that half of the landscaping area (0.4 acre) will have an irrigation system and has an annual average water irrigation demand of 34 inches per year. The maximum allowable based on current watering restrictions is ¾ inches X* 52 weeks per year = 39 inches per year.

      The average annual irrigation requirement= (0.40-acre) (34 in) /12 = 1.13 acre-feet.
      1.13 acre-feet * 325,851 gallons/12 = 30,772 gallons per month.

    - *Step 1b* – Calculate potential graywater demand

      The commercial building is for a business with 40 FTE. The anticipated use of graywater is for urinal and toilet flushing. The building will use low-volume fixtures.

      Using data from U.S. Green Building Council (USGBC)

Non-residential uses per day		
	Water Closet	Urinal
Female	3	0
Male	1	2
Flow rate in gallons/ use		
	Water Closet	Urinal
Conventional	1.6	1
Low Flow	1.1	0.5

For 40 FTE, assume 20 women and 20 men. The business is open 7 days per week, with an average of 30 days per month.

Monthly graywater usage for women =
20 women * 30 days/ month * 3 uses per day * 1.1 gallons per use = 1,980 gallons/month

Monthly graywater usage for men =
20 men * 30 days/ month * 1 use per day * 1.1 gallons per use = 660 gallons/month for water closet (WC)
20 men * 30 days/ month * 2 uses per day * 0.5 gallons per use = 600 gallons/month for urinal

Graywater use for flushing = 1,980 + 660 + 600 = 3,240 gallons/month

Total Graywater use for flushing = 3,240 * 2 = 6,480 gallons/month

- *Step 1c* – Calculate potential potable water demand

  The commercial building is for a business with 40 FTE. The business does not plan to use rainwater as potable water.

- *Step 1d* – Calculate total water demand

Usage	Monthly Average Demand
Irrigation	30,722 gallons
Graywater (flushing)	6,480 gallons
Irrigation and Graywater (flushing)	37,252 gallons

- *Step 2* – Determine average rainfall values

  Based on the data provided in Table 3.5-1, the annual average rainfall is 4.15 inches, the maximum monthly average occurs in the month of August of 7.9 inches, and the minimum monthly average occurs in the month of November of 1.9 inches.

- *Step 3* – Calculate the roof capture potential/catchment area

  Calculate the roof area routed to roof drains. In this case the entire roof is routed to roof drains. For water supply estimates the applicant assumes that with all the losses the roof catchment system typically captures 0.46-gallons per square foot of roof per inch of rainfall (Oregon, 2009).

  Roof Capture potential peak month = (catchment area of 20,000 sq ft) (0.46) (7.9 inches of rain in August) = 72,680 gallons

  Roof Capture potential average month = (catchment area of 20,000 sq ft) (0.46) (4.15 inches of annual average rainfall) = 38,180 gallons

- *Step 4* – Decide on the water use goal of the Rainwater Harvesting System

  To size the cistern, the owner and applicant must decide on the overall goal of the system. This decision could be influenced by many factors such as cost, Leadership in Energy and Environmental Design (LEED) building credits, maintenance, and public perception.

  In this example the owner sees that the total water demand is 37,252 gallons per month; therefore, the owner decides to install a 45,000-gallon cistern sized to collect slightly more than the runoff for the average month.

- *Step 5* – Determine the removal effectiveness (E) for the Rainwater Harvesting System

  The cistern volume is 45000 gallons.
  The roof catchment area is 20,000 square feet.
  The equivalent impervious area (EIA) is 16,640 square feet [0.832 x 20,000] where 0.832 is the average annual runoff coefficient from Table A-1.
  The storage volume = [(45,000 gallons/(7.48 gallons/cf))/16,640 square feet * (12 inches/foot)] = 4.4 inches / square foot.

Usage	Equation ((gallons/month)/EIA) * conversion factor	Average Demand (in/day)	Efficiency % (Figure 3.5-4)
Irrigation	(30,772 / 16,640) * 0.0527	0.1	65%
Irrigation and Graywater	(37,252 / 16,640) * 0.0527	0.12	70%

The proposed system meets a majority of the stormwater quality treatment requirements of 80% average annual removal effectiveness. The remainder of the treatment and the downstream peak attenuation for the full roof runoff and the remainder of the site will have to be provided for the 100-year/24-hour design storm since the rainwater harvesting system only provides water quality credit.

- *Step 6* – Confirm Local Design Criteria and Applicability

  Check with local officials and other agencies to determine if any additional restrictions and/or surface water or watershed requirements may apply.

- *Step 7* – Confirm Local Design Criteria and Applicability

  A RHS for potable water use requires permits from the Sarasota County Health Department and Sarasota County Development Services. The owner must also check with local officials and other agencies to determine if any additional restrictions and/or surface water or watershed requirements may apply.

3.5.4 Construction

The following items should be considered before construction begins:

3.5.5 Operation and Maintenance

The operation and maintenance entity is required to provide for the inspection of the total surface water management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections shall be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter.

3.5.5.1 Maintenance

The owner or operator should keep maintenance records or a log of activities and make them available for recertification. The records or log of activities should include data on the following:

A. Harvesting volume (irrigation or graywater use) measured using a flow meter.

B. Observations on the harvesting cycle times and replacement of parts.

C. Clogging frequency and maintenance of the filters.

D. Maintenance of the pump.

E. Cistern overflow volume.

F. Observations of the irrigation system and replacement of parts.

3.5.5.2 Suggested Inspection Items

As part of the maintenance log of activities, the following tasks must be completed by an appropriate Florida-registered and -licensed professional:

A. Inspect gutters for clogging. Remove any debris in the gutters, downspouts, or first-flush diverter.

B. Inspect cistern for debris or algae. Remove any debris in the gutters, downspouts, or first-flush diverter.

C. Inspect the irrigation system for clogging. Replace clogged sections.

D. Inspect overflow or discharge to ensure proper operation.

E. Provide annual report of maintenance and inspection information to Sarasota County Government and the Southwest Florida Water Management District.

3.5.5.3 Testing the System

The harvesting pump and the filtration system must be tested before they are certified for use by an appropriate Florida-registered and -licensed professional. If an irrigation system is used, it should be tested regularly to ensure proper operation of the float gauges, pump, timer, meter, and precipitation shut off. All testing records must be kept or permanently logged for submission or review.

Irrigation systems which use harvested rainwater should be tested annually to ensure proper operation of the first-flush diverter, filter, cistern, level indicator, pump, timer, meter, and precipitation shut off. All testing records must be kept or permanently logged for submission or review.

Graywater systems which use harvested rainwater must be tested annually to ensure proper operation of the first-flush diverter, filter, cistern, level indicator, pump, timer, meter, fine particulate filter, and backflow preventer. All testing records must be kept or permanently logged for submission or review.

Potable water systems which use harvested rainwater should be tested in accordance with Sarasota County Health Department rules to ensure proper operation of the first-flush diverter, filter, cistern, level indicator, pump, timer, meter, fine particulate filter, disinfection system, and backflow preventer. The testing procedures include regular submittal of bacteriological sampling results. All testing records must be kept or permanently logged for submission or review.

3.5.5.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of RHS. Maintenance responsibility for a RHS must be vested in a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.5.6 References

1. International Code Council, Inc., *2007 Florida Building Code, Plumbing* 1st Printing. Tallahassee, FL. February, 2008.
2. Oregon Department of Consumer and Business Services, Building Codes Division, *Oregon Smart Guide: Rainwater Harvesting*. Salem, OR. February, 2009.
3. Texas Water Development Board, *The Texas Manual on Rainwater Harvesting*, 3rd Edition. Austin, TX. 2005.
4. Dukes, M.D., et al. *Frequently Asked Questions about Landscape Irrigation for Florida-Friendly Landscaping Ordinance*. ENH1114. IFAS. Gainesville, FL. 2008.
5. U.S. Green Building Council, *Water Use Reduction Additional Guidance*, Revision 3. Washington, D.C., updated July 14, 2011.

SECTION 3.6: Detention with Biofiltration

3.6 DETENTION WITH BIOFILTRATION

Key Considerations	**Practice Intent:** ▪ Detain, and treat stormwater close to source. **Design Criteria:** ▪ It is recommended for the drainage area to be 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible. Treatment area consists of grass filter, sand bed, underdrain, ponding area, organic/mulch layer, planting soil, and vegetation. ▪ Separated from water table by structural means. **Advantage/Benefits:** ▪ Applicable to small drainage areas. ▪ Applicable to high water table conditions. ▪ Good retrofit capability. ▪ Can be planned as an aesthetic feature. ▪ Used where contamination is a threat. **Disadvantages/Limitations:** ▪ Requires landscaping. ▪ Requires underdrain system. **Maintenance Requirements:** ▪ Inspect and repair/replace treatment area components. ▪ Remove trash, litter, and sediment. **Monitoring/Record Keeping:** ▪ Maintain record of fertilizer application. ▪ Conduct biennial visual observation after rainfall event.
Pollutant Removal Potential	**H** **Total Suspended Solids** **H** **Nutrients**—Total Phosphorus/Total Nitrogen **H/M** **Metals**—Cadmium, Copper, Lead, and Zinc **M** **Pathogens**—Coliform, Streptococci, E.Coli
Stormwater Management Suitability	☒ **Water Quality** ☒ **Volume and Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Yes **High-Density/Ultra-Urban:** Yes **Drainage Area:** It is recommended for the drainage area to be 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible. **Shallow Water Table:** Seasonal High Water Table should be hydraulically separated by structural means. **Soils:** Planting soils must meet specified criteria; no restrictions on surrounding soils.
Other Considerations:	Use of native plants is highly recommended.

L—Low, **M**—Moderate, **H**—High

3.6.1 General

3.6.1.1 Overview and Intent

Detention systems with biofiltration, or biofiltration systems, are shallow depressions with underdrains used as structural stormwater controls to capture and treat stormwater runoff (Figure 3.6-1). Within these systems, soils, mulch, planted vegetation, and an anoxic zone facilitate treatment and remove pollutants from the runoff. The biofiltration system is lined to keep it separate from the surrounding water table and to maintain an anoxic zone in the bottom of the system. Separating the biofiltration system from the water table has a number of advantages:

- An artificial anoxic zone can be created to facilitate improved nitrogen removal.
- The permanently wet zone serves as a source of water for plants within the biofiltration system.
- Allows biofiltration systems to be used where the SHWT table is close to the surface.
- The system can be used where there may be concerns about contamination of groundwater, such as gas stations.
- The system can be used adjacent to structures that may be adversely impacted by groundwater, such as building foundations and road foundations.

As is customary with LID practices, numerous biofiltration systems distributed throughout a subbasin instead of a single large stormwater basin help facilitate treatment near the source. Although any one treatment area may be small, the cumulative effect can be significant.

3.6.1.2 Applicability

Water Quantity Control

Biofiltration systems are designed primarily for addressing stormwater quality. Although biofiltration systems will provide some attenuation of peak flows, they will most likely not provide sufficient storage capacity to meet Sarasota County and SWFWMD water quantity control criteria.

Water Quality Control

Biofiltration systems can be more effective than conventional detention systems due to the increased interaction of stormwater runoff with soil, microbes, and vegetation enhancing biogeochemical processes and improving water quality. Treating stormwater by biofiltration can be very effective due to the variety of chemical, physical, and biological removal mechanisms.

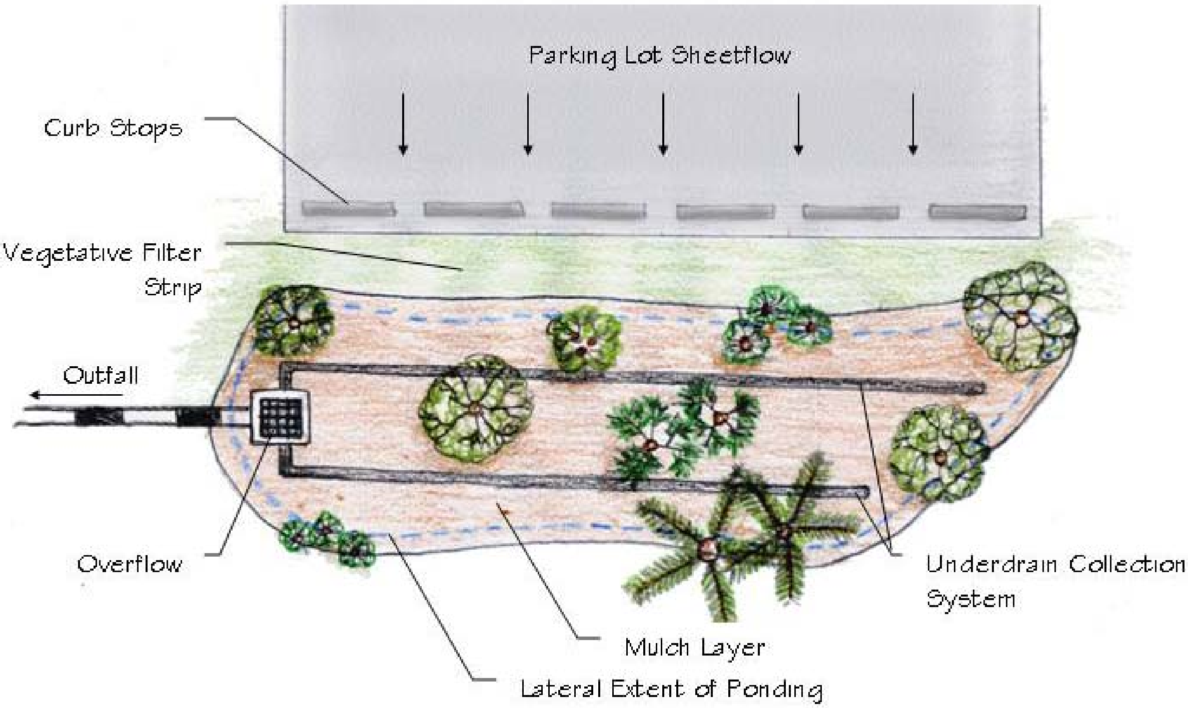

Figure 3.6-1 Plan View Illustrating a Detention System with Biofiltration

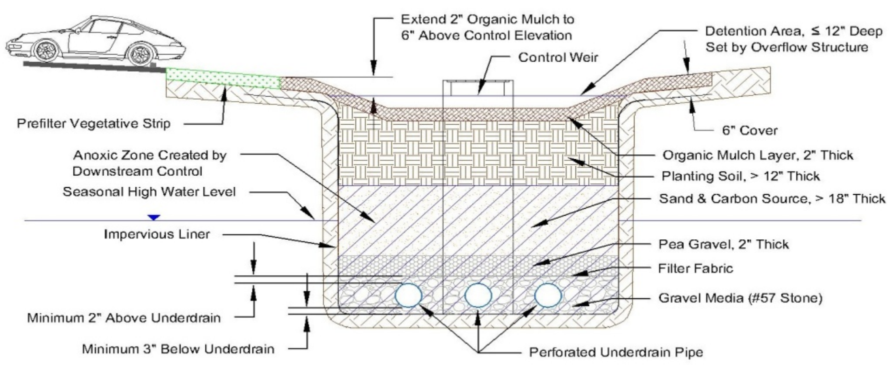

Figure 3.6-2 Cross Section View of a Detention System with Biofiltration

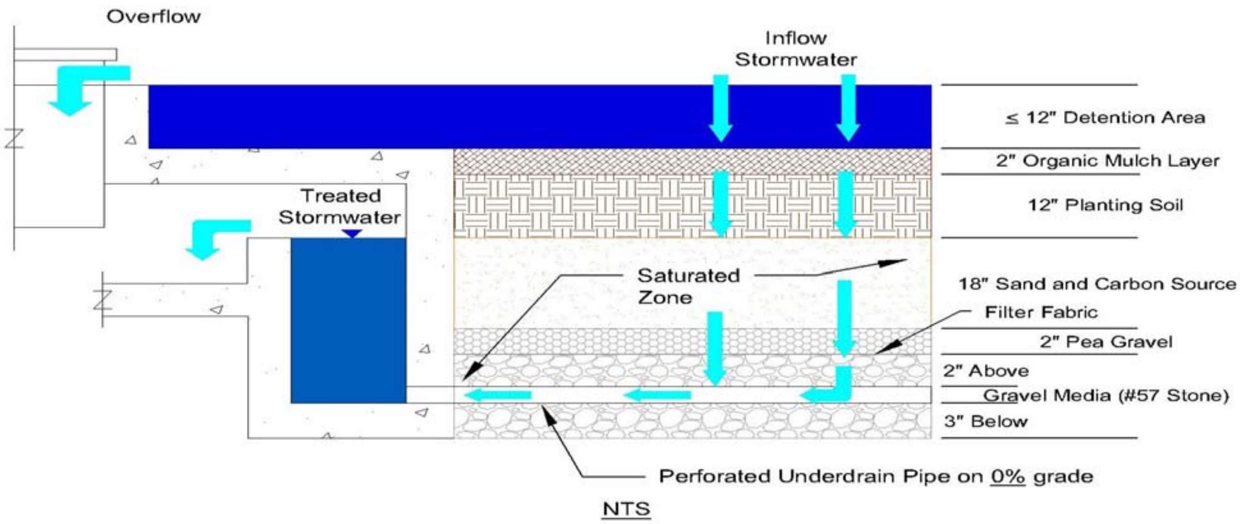

Figure 3.6-3 Cross Section View of System with Overflow

General Feasibility

Biofiltration systems are suitable for many types of development, from single-family residential to high-density commercial projects. Because the shape and sizing of systems are relatively flexible, the systems can be incorporated into many landscaped designs. These systems are an ideal structural stormwater control for use near impervious areas such as roadway medians, parking lot islands, and swales. Biofiltration systems are also well suited for treating runoff from pervious areas, such as recreational fields, golf courses, or landscaped areas. Biofiltration systems may also be used to treat roof runoff, in which case they could be installed with all or a part of the system above ground. If biofiltration systems are installed above ground, the same fundamental design requirements would have to be met as with in-ground biofiltration systems and the biofiltration system would have to discharge through an under-drain system. Biofiltration systems are not suitable for regional stormwater control.

Physical Constraints

When evaluating the appropriateness of a biofiltration system, an applicant should consider some of the physical constraints associated with this type of treatment system, including:

A. Drainage Area – Biofiltration systems that treat a drainage area greater than 5 acres will need prior approval by Sarasota County and SWFWMD.

B. Seasonal High Water Table – separated by structural means from hydraulic contribution of the surrounding water table.

C. Soils – Stormwater should pass through 2-3 inches of mulch and a minimum of 12 inches of planting soil and 18 inches sand with carbon source before entering the perforated pipe.

3.6.2 Design Considerations and Requirements

The following criteria are to be considered **minimum** standards for the design of a detention system with biofiltration in Sarasota County. Consult with SWFWMD to determine whether any variations must be made to these criteria or if additional standards must be followed.

3.6.2.1 General

A detention system with biofiltration should consist of the following (see Figure 3.6-1):

A. *Prefilter strip* – Where feasible, a vegetative prefilter or grass channel strip between the contributing drainage area and the ponding area to capture course sediments and reduce sediment loading to the detention area. The applicant may provide other measures to minimize the sediments entering the detention area in lieu of a prefilter strip. Biofiltration systems that do not include a prefilter strip or other measures must be subject to additional testing criteria.

B. *Ponding area* – An area that provides temporary surface storage (less than 12 inches) for runoff before infiltration through the soil treatment bed.

C. *Organic mulch layer* – A 2-3 inch layer that attenuates heavy metals, reduces weed establishment, regulates soil temperature and moisture, and adds organic matter to the soil.

D. *Planting soil filter bed* – A layer that provides at least 12 inches of planting media for vegetation within the basin as well as a sorption site for pollutants and a matrix for soil microbes.

E. *Sand bed with carbon source* – A layer at least 18 inches thick at the bottom of the biofiltration system that facilitates denitrification under anoxic conditions. This layer also sorbs additional pollutants.

F. *Woody and herbaceous plants* – Florida-friendly plants that provide a carbon source for the biofiltration system, help facilitate microbial activity, and improve infiltration rates. Roots should be kept away from the underdrain.

G. *Underdrain* - A system facilitating the drainage of stormwater through the soil media.

H. *Control Structure* - A structure that creates an anoxic zone up to the elevation of the top of the sand layer.

I. *Overflow pipe or spillway* – a structure to allow rainfall events that exceed cell volume capacity to bypass the system. The discharge invert should be set no higher than 12 inches above the soil surface with the applicable downstream erosion-control measures.

3.6.2.2 Location and Planning

Biofiltration systems are designed for intermittent flow and should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

Locations of biofiltration systems should be integrated into the site-planning process, and aesthetic considerations should be taken into account in their siting and design. All control elevations must be specified to ensure that runoff entering the facility does not exceed the design depth. Biofiltration systems can be installed partly or fully above ground as a planter box to treat roof runoff. However, these systems must still be lined and drained by an underdrain.

3.6.2.3 Sizing Requirements

Prefilter Strip (if feasible) or other measures

A. The prefilter strip design will depend on topography, flow velocities, volume entering the buffer, and site constraints.

B. The prefilter strip is typically a vegetated or grassed channel.

C. Flow rates entering the biofiltration system must be less than 1 foot per second to minimize erosion.

Ponding Area

A. The maximum ponding depth should be no more than 12 inches below the overflow structure.

B. The recovery time must be less than 72 hours.

Organic Mulch Layer

A. The surface organic mulch layer should be 2-3 inches deep and cover the surface of the basin to at least 6 inches above the expected high water line.

B. Mulch depth should never exceed 4 inches or soil aeration may be reduced.

C. Hardwood mulch should be used due to its higher pH, improved microbial activity, and slower decomposition rate. Examples of acceptable mulches are those made from melaleuca or eucalyptus trees. Pine bark or pine straw is not acceptable.

D. Partially composted mulch is acceptable, especially in the lower parts of the depression as this will reduce the tendency of the mulch to float.

Planting Soil Filter Bed

A. The planting soil filter bed must be at least 12 inches thick.

B. The bed material should be sandy loam, loamy sand, or loam texture.

C. Clay content should be between 3 and 5%.

D. Soil pH should be between 5.5 and 6.5.

E. Soil organic matter content should be between 3 and 5%. Soil amendments to raise the organic matter content should t have a carbon-to-nitrogen ratio of at least 50%.

F. The soil mix must be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches in size.

G. The suggested hydraulic conductivity for the planting soil is 4 to 12 inches per hour. Design hydraulic conductivities that fall outside this range must be agreed to in writing during the pre-application meeting.

Sand Bed with Carbon Source

A. The sand bed with a carbon source must be at least 18 inches thick.

B. The unit weight should be more than 70 pounds per cubic foot when dry.

C. No more than 5% of the particles should pass through a #200 sieve.

D. The media should be more than 50% uniformly graded sand by volume and the sand must not contain shale.

E. The media water holding capacity should be at least 30% as measured by porosity.

F. The vertical permeability must be at least 2 inches per hour at the specified unit weight noted above.

G. The media should have an organic content of at least 5% by volume. The organic content must be in the form of 1-inch hardwood chips (e.g. melaleuca or eucalyptus woodchips) evenly distributed throughout the layer.

H. The media pH should be between 6.5 and 8.0.

I. The concentration of soluble salts should be less than 3.5 g (KCL)/L.

J. The sorption capacity of the sand should exceed 0.005 mg OP/mg media.

Under-Drain System

A. Pipe

1. Underdrain pipe should be at least 4-inch-diameter PVC or HDPE pipe.
2. Perforations must meet the AASHTO M 36 or M 196 requirements.
3. Pipe should be spaced no more than 10 feet apart on center.

B. Gravel media

1. Pipe must be laid on 3 inches of double-washed No. 57 aggregate and then filled around both sides of the pipe and over the top at least 2 inches.
2. Gravel must extend to the full width and length of the Sand and Carbon Source Layer to allow for an even flow through this layer.
3. The course gravel layer must be overlaid with non-woven, non-degradable filter fabric that meets the geotextile requirements provided in FDOT Design Standards Index No. 199 for Geotextile Type D-3.
4. Filter fabric must be covered with 2 inches of ¼-inch to ½-inch double-washed pea gravel to reduce the likelihood of clogging.
5. Pea gravel must extend to the full width and length of the Sand and Carbon Source Layer to allow for an even flow through this layer.

C. Control Structure

1. A control structure that creates an anoxic zone to the top of the sand layer must be placed downstream of the underdrain system.
2. The control structure should be designed to preclude a siphon from forming.
3. The control structure should be designed so that it does not inhibit maintenance and cleanout of the underdrain system.

3.6.2.4 Discharge Requirements

The biofiltration system is primarily a water quality treatment system and does not need to meet any specific discharge requirements. However, an overflow structure and non-erosive overflow channel must be provided to safely pass flows that exceed the storage capacity of the biofiltration system to a stabilized downstream area or watercourse. The complete stormwater treatment system for the site must meet SWFWMD and Sarasota County water quantity discharge requirements.

3.6.2.5 Recovery Requirements

The appropriate Florida-registered and -licensed professional must demonstrate through an underdrain recovery calculation or by underdrain recovery modeling that under high tailwater conditions there is no standing water in the biofiltration system 72 hours after the detention volume is applied.

The assumed hydraulic conductivity for the planting soil must be stated clearly as this will be used when testing biofiltration systems.

3.6.2.6 Water Quantity Credits

Biofiltration systems are typically used for water quality treatment and not for flow attenuation. However, the effectiveness of a biofiltration system at attenuating peak flows can be calculated using one of the following procedures:

A. Calculating the Curve Number (CN) for the biofiltration area and including this in the area weighted CN for the entire site.

B. Explicitly modeling the hydraulic functioning of the biofiltration system—including the underdrain and overflow control structures.

3.6.2.7 Water Quality Treatment Requirements/Credits

No specific treatment requirement is associated with a single biofiltration system. These systems are intended to be part of a treatment train, where each practice in the train provides incremental water quality benefits. The level of treatment that can be expected from these systems is based on the average annual volume of water captured and filtered by the biofiltration system and the removal efficiency of biofiltration system.

The annual average pollutant-load reduction for nitrogen, and phosphorus must be calculated for a biofiltration system to be considered part of the water quality treatment. Removal efficiencies for both constituents must be developed using one of the following methods:

A. *Assumed efficiencies* – An 80% removal efficiency will be excepted for systems that are designed to the minimum recommended design criteria in this Manual. Systems that are designed with substantial deviations from the minimum recommend in this manual the removal efficiency shall be determined for the specific design andmust be discussed with SWFWMD and County staff at the pre-application meetings and confirmed using water quality monitoring for a duration and frequency agreed to by the SWFWMD and County Staff at the pre-application meetings. If the assumed removal efficiencies are found to exceed the measured removal efficiencies, the County and SWFWMD may request that the property owner perform on-site mitigation to achieve the permitted removal efficiencies.

B. *Literature values* – These must be agreed to in writing by SWFWMD and County staff at the pre-application meeting.

The percentage of the average annual runoff volume that is filtered by the biofiltration system must be estimated using one of the following methods:

A. *Continuous simulation* – A continuous simulation of the biofiltration system using an applicable long-term rainfall record (at least 20 years).

B. *Design Curve* - Figure 3.6-4 may be used to determine the percentage of the average annual volume of water filtered or captured by the biofiltration system. This figure requires that the equivalent impervious area (EIA) and detention volume are known. The EIA is equal to the mean annual runoff coefficient (TableA-1) multiplied by the drainage area. It should be noted that when using Table A-1 a directly connected impervious area should be treated as 100% DCIA rather than having a CN of 98.

The average annual pollutant load reduction can then be calculated by multiplying the removal efficiency by the percentage of the average annual runoff that is captured and filtered by the biofiltration system. For example, a system that captures and filters 70% of the average annual runoff volume and has a removal efficiency of 80% for nitrogen will result in a 56% average annual nitrogen load reduction.

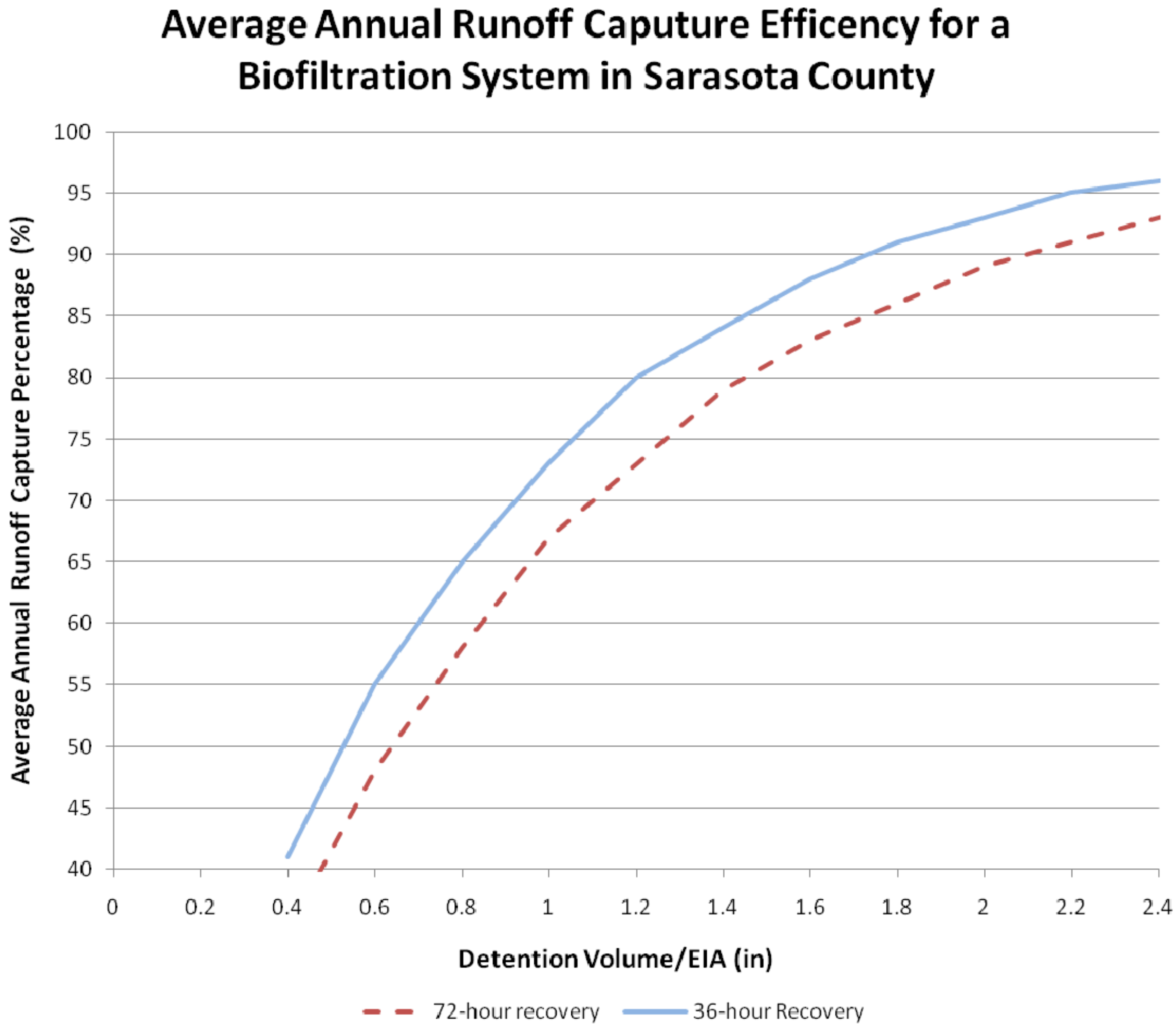

Figure 3.6-4 Average Annual Runoff Capture Efficiency for a Biofiltration System in Sarasota County

Where: EIA is the Equivalent Impervious Area for the contributing area and the Detention Volume is the surface detention volume of the biofiltration system.

3.6.2.8 Maintenance Access

Access to the detention area must be provided at all times for inspection, maintenance, and landscaping upkeep. There must be sufficient space around the biofiltration system to allow accumulated surface sediments to be removed and possibly for underdrains to be cleaned out or replaced if they should fail infiltration tests or inspection.

To facilitate maintenance of the underdrain system, capped and sealed inspection and cleanout ports that extend to the surface of the ground should be provided at the following locations for each drainage pipe at a minimum:

The beginning and end of each run of pipe.
At every 50 feet or every bend greater than 45 degrees, whichever is shorter.

3.6.2.9 Safety Features

Detention systems with biofiltration generally do not require any special safety features. Fencing these facilities is not generally desirable. Railings or a grate can be used to address safety concerns if the area is designed with vertical walls.

3.6.2.10 Landscaping

Landscaping enhances the performance and function of biofiltration systems. Selecting plant material based on hydrologic conditions in the basin and aesthetics will improve plant survival, public acceptance, and overall treatment efficiency. Native or Florida-friendly plants should be selected. All landscaping recommendations should be considered before storm flows are conveyed to the biofiltration system:

Landscaping of Catchment

A. The unpaved contributing area should be well vegetated to minimize erosion and sediment inputs to the biofiltration system.

B. Where feasible a prefilter vegetative strip or vegetative swale should be installed.

C. If used, trees should be spaced 12 to 15 feet apart depending on the type.

D. Plants should be placed at irregular intervals.

E. If woody vegetation is used, it should be placed along the banks and edges of the biofiltration system, not in the direct flow path.

F. Only species well adapted to the regional climate should be used.

G. Species planted in well-drained media should tolerant short-term ponding as well as periods of low soil moisture.

3.6.3 Biofiltration Design Procedure

The following procedures are intended to guide an applicant through the design of a detention system with biofiltration:

3.6.3.1 Design Steps

- *Step 1* – Determine if the development site and conditions are appropriate for the use of a biofiltration system. Consider the Application and Site Feasibility Criteria in Subsections 3.6.1.2 (Physical Constraints) and 3.6.2.2 (Location and Siting).

- *Step 2* – Determine the drainage area and the equivalent impervious area (EIA) for the drainage area. Table A-1 can be used to estimate the EIA [EIA = C x Drainage Area].

- *Step 3* – Compute the maximum detention volume that will be detained in the surface storage of the biofiltration system (maximum depth 12 inches).

- *Step 4* – Set design elevations and dimensions of facility. See Subsection 3.6.2.3, Ponding Area, Subsection C.

- *Step 5* – Design a pretreatment system if practicable — either a prefilter strip or vegetative swale.

- *Step 6* – Size the underdrain system and downstream control structure. See Subsection 3.6.2.3, Underdrain System (Sizing requirements - underdrain)

- *Step 7* – Design the emergency overflow. An overflow must be provided to bypass and/or convey larger flows to the downstream drainage system or stabilized watercourse. Non-erosive velocities need to be ensured at the outlet point.

- *Step 8* – Determine the Average Annual Pollutant-Load Reduction. This annual average pollutant-load reduction for each constituent must be calculated using the detention volume determined in Step 3 and the EIA determined in Step 2. See Subsection 3.6.2.7

- *Step 9* – Calculate the peak attenuation credit.

- *Step 10* – Prepare the vegetation and landscaping plan. A landscaping plan for the detention area should be prepared to indicate how the area would be established with vegetation.

3.6.3.2 Design Example

Assume that a stormwater BMP is needed to help meet the water quality objectives of a site. The portion of a site analyzed in the example includes 1 acre of paving plus an area that is 80 feet by 30 feet to be used for a detention with biofiltration system. The following are sample calculations for determining the pollutant load removal efficiency of a detention with biofiltration system.

- *Step 1* – Assume that the applicant has determined that the site meets the criteria specified in 3.6.1.2 and 3.6.1.3. Therefore, a biofiltration system is an appropriate choice for a BMP on this site.

- *Step 2* – The contributing area is a 1-acre paved surface plus a 0.06-acre biofiltration system. The mean annual runoff coefficient for the paved surface and the biofiltration surface is 0.823 (Table A-1). Therefore, the EIA for the paving and the biofiltration system is 0.872 acre = [1 * 0.823 + 0.06 * 0.823].

- *Step 3* – The area available for the biofiltration system is limited to approximately 80 feet by 30 feet (Area at top of storage = 80 * 30 = 2400 sf). Therefore, using the maximum detention depth of 1 foot, and assuming a side slope of 3:1 (area and bottom of storage = 74 * 24 = 1776 sf) the maximum detention volume detained on the surface of the biofiltration area is calculated to be 2,088 = [((2400 sf + 1776 sf)/2) * 1 foot)] cubic feet.

- *Step 4* – The design elevations are then set to meet the criteria specified in 3.6.2.3.

- *Step 5* – Assume that the applicant has found that there is sufficient space for a prefilter strip. This reduces the frequency of infiltration rate testing to once every 3 years, rather than once every 18 months, which is required if no prefilter strip is included.

- *Step 6* – The applicant then sizes the underdrain to recover in 36 hours and to create the anoxic zone which is 24 inches deep. This meets the criteria detailed in 3.6.2.3 and 3.6.2.5.

- *Step 7* – An emergency overflow and the appropriate erosion controls would then be designed to meet the discharge from the 100-year/24-hour design storm event in Sarasota County.

- *Step 8* – The average annual pollutant removal efficiency would be calculated. Dividing the detention volume by the EIA gives a detention volume of 0.66 (2088 cf / .872 acre * 12 / 43560) inch over the EIA. Figure 3.6-3 shows that approximately 58% of the average annual runoff would be filtered by the biofiltration system. Given that the system provides an 80% removal of nitrogen, it can be calculated that the system would achieve a 46% reduction in nitrogen loading from the paved area.

- *Step 9* – The applicant would then calculate the peak attenuation credit.

3.6.4 Operation and Maintenance

3.6.4.1 Maintenance

Several ways to maintain the system and to continue to receive stormwater credits include:

A. Prune and weed to keep any structures clear.

B. Maintain/mow the prefilter strip or swale at least twice during the growing season and remove clippings from the flow path.

C. Replace mulch where needed when erosion is evident.

D. Remove trash and debris as needed.

E. Replace mulch over the entire area every 2 to 3 years.

F. Remove sediment from inflow system and outflow system as needed.

G. Stabilize any upstream erosion as needed.

H. Remove and replace any dead or severely damaged vegetation.

3.6.4.2 Inspection

The operation and maintenance entity is required to provide for the inspection of the total surface water management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections shall be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter. The report is due within 30 days of the date of inspection. At a minimum the following should be inspected:

A. Inspect inflow/outflow points for any clogging.

B. Inspect prefilter strip/grass channel and detention area for erosion or gullying.

C. Inspect trees and shrubs to evaluate their health.

D. Inspect the underdrain system.

3.6.4.3 Testing

Testing must be conducted by the appropriate Florida-registered and -licensed professional to provide reasonable assurance that the detention with biofiltration system is functioning as intended. Results as well as remedial actions should be reported to SWFWMD and Sarasota County. Formatting requirements and details on how reports should be submitted must be discussed and agreed to during the permitting procedure. For sites that include a large number of biofiltration systems, a testing schedule in which a representative sample of biofiltration systems are tested at the appropriate interval may be agreed to at the pre-application meeting or during the permitting process. Testing must include the following:

A. The planting soils pH should be tested every 3 years. Planting soils pH should be between 5.5 and 6.5. If soil pH is below 5.5, lime shouldt be applied to raise the pH to 6.5.

B. Biofiltration systems that include a prefilter strip require that a double-ring infiltration test be performed every 3 years at three locations in the bottom of the basin to confirm design infiltration rates. Biofiltration systems that do not include a prefilter strip require that a double-ring infiltration test be performed every 18 months at three locations in the bottom of the basin to confirm design infiltration rates. If two out of three tests are below the design criteria (Section 3.6.2.5) or the average rate of the three tests is below the design criteria, the mulch layer and surficial soil layer must be restored. Core aeration or cultivating of non-vegetated areas may be sufficient to ensure adequate filtration.

3.6.4.4 Additional Maintenance Considerations and Requirements

Regular inspection and maintenance are critical to the effective operation of detention systems with biofiltration. Maintenance responsibility for all LID and stormwater facilities must be vested in a responsible authority by a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

3.6.5 References

1. Saxton, K.E., and W.J. Rawls, 2006. *Soil Water Characteristic Estimates by texture and Organic Matter for Hydrologic Solutions*. *Soil Sci Soc Am J* 70:1569-1578. (http://hydrolab.arsusda.gov/soilwater/Index.htm)
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CHAPTER 4 - Permitting Guide

4.1 INTRODUCTION

As with any BMPs for stormwater treatment, LID practices must comply with Sarasota County permitting requirements as well as those criteria adopted in Environmental Resource Permitting (ERP) rules. These requirements are not identical, but stormwater treatment systems incorporating LID practices can be designed in a manner that complies with all regulatory criteria. The purpose of this chapter is to describe the criteria in ERP rules applicable to stormwater treatment systems incorporating LID practices and to provide design examples which meet both ERP and County criteria.

ERP rules require as a condition of permit issuance that an applicant demonstrate a proposed system will not adversely affect the quality of receiving waters such that water quality standards will be violated. Other conditions of issuance generally applicable to the design of stormwater treatment systems incorporating LID practices address flood protection, effectiveness of system performance and function, protection of wetlands, fish and wildlife and maintenance of minimum flows and levels established pursuant to Chapter 373.042, F.S.. Applicants are advised to consult Rules 40D-4 and 40D-40, Florida Administrative Code for a complete list of all applicable ERP criteria. Similarly, the Sarasota County Land Development Regulations require that an applicant demonstrate a proposed system will have no discharge from any stormwater management facility that causes or contributes to a violation of water quality standards in waters of the State as provided for in State Statues.

4.2 COMPLIANCE WITH ERP “PRESUMPTIVE” CRITERIA

The ERP Basis of Review is a document used to identify the usual procedures and information used in evaluating an ERP application for compliance with the conditions of issuance. Stormwater treatment systems designed using the specific criteria in the Basis of Review are presumed to provide reasonable assurance of compliance with state water quality standards. Additionally, alternative methods that provide treatment equivalent to systems designed using the criteria specified in the Basis of Review can also be presumed to provide reasonable assurance of compliance with water quality standards based on information specific to the proposed design. Accordingly, these criteria are often referred to as “presumptive” criteria. Certain LID practices may be designed in a manner that is consistent with these “presumptive criteria”.

Presumptive Criteria for a Volume Based Treatment System		
	Southwest Florida Management District	Sarasota County
Requirement	½ inch of rainfall	The runoff from the first 1 inch of rainfall
Equation (cubic feet)	Area (acres) * 0.5 inch * (43,560 square feet /acre) / (12 inches/foot)	Area (acres) * C * 1 inch * (43,560 square feet /acre) / (12 inches/foot)

*C = the weighted coefficient of runoff

Design criteria in the ERP Basis of Review are intended to be flexible, however, and other BMPs may be permitted under “non-presumptive” criteria. Applicants proposing “non-presumptive” stormwater treatment BMPs, including alternative LID practices, must provide reasonable assurance, based on information specific to the proposed design, that state water quality standards will be met. This demonstration of reasonable assurance under “non-presumptive” criteria involves a demonstration of an annual pollutant load reduction of 80% (95% for direct discharges to Outstanding Florida Waters) following the pollutant removal goals established in the State Water Resource Implementation Rule (Rule 62-40, Florida Administrative Code).

Applicants proposing multiple BMPs in a “treatment train” design are advised that these systems must be designed to meet exclusively the volumetric requirements of the presumptive criteria or the pollutant load removal requirements of the non-presumptive criteria.

4.2.1 Shallow Bioretention

A stormwater treatment system incorporating shallow bioretention may be permitted under ERP “presumptive” criteria based on the criteria in the Basis of Review for online systems utilizing retention. Criteria for these systems are found in Section 5.2(c) of the ERP Basis of Review. Additionally, the system must be designed consistent with the minimum design criteria in Section 3.1 of this Manual. Note: the total water treatment volume must be available with 72 hours.

Assuming the same site parameters used in the design example for Shallow Bioretention (Section 3.1). The site is 2 acres with 1 acre of paving and 1 acre of pervious grass area. The seasonal high water table is found to be 2 feet below the surface. The available area for the proposed retention area is 80 feet by 30 feet or 2400 square feet at the top of bank and the side slopes of the retention area are proposed at 4:1.

- *Step 1* – Treatment Required

  Weighted coefficient of runoff (C) = ((Impervious area * 0.95) + (Pervious grass area * 0.2))/ total area

  C = ((1 * 0.95) + (1 * 0.2)) / 2 = 0.575

	Equation	Treatment Required
District	2 acres * 0.5 inch * conversion	3,630 cubic feet
County	2 acres * C * 1 inch * conversion	4,175 cubic feet

* Conversion = 43,560 (square feet/ acre)/ 12 (inch/foot)

- *Step 2* – Calculate the treatment volume provided

  To calculate the volume in the system by using the average area methodology:

  The area at the top of bank = 80’ x 30’ = 2,400 square feet

  The area at the bottom the storage area = [80’ – (2 x side slope)] x [30’ – (2 x side slope)] = 1,584 square feet

  Volume = (Top area + Bottom area)/2 * storage depth = (2,400 square feet + 1,584 square feet)/2 * 1 ft = 1,992 cubic feet.

- *Step 3* – Calculate the additional treatment volume required

	District	County
Treatment Required	3,630 cubic feet	4,175 cubic feet
Treatment Provided	1,922 cubic feet	1,922 cubic feet
Additional Treatment Required	3,630 - 1,922 = 1,638 cubic feet	4,175 - 1,922 =2,183 cubic feet

  The additional treatment volume must be accounted for in an onsite downstream stormwater management system.

4.2.2 Pervious Pavement

A stormwater treatment system incorporating pervious pavement may be permitted under ERP “presumptive” criteria based on the criteria in the Basis of Review for online systems utilizing retention. Criteria for these systems are found in Section 5.2(c) of the ERP Basis of Review. Additionally, the system must be designed consistent with the minimum design criteria in Section 3.2 of this Manual. Note: the total water treatment volume must be available with 72 hours.

The following is a design example for a pervious pavement system which complies with both the ERP Basis of Review and Section 3.2 of this Manual. The site area is a 2-acre parking lot with 30% being traditional pavement and 70% being designed as pervious pavement. The pervious pavement cross section consists of a 4 inch thick pervious concrete (Void space 20%) and a 6 inch thick #57 stone pavement reservoir (Void space 25%).

- *Step 1* - Treatment Volume Required

  To calculating the runoff from the first 1 inch rainfall treatment volume required the applicant must first calculate the weighted coefficient of runoff for the contributing drainage basin. When calculating the weighted coefficient of runoff the pervious pavement system will be assumed to have a coefficient of runoff consistent with a dry pond, C = 0.8. From the project parameters above it can be calculated that the site is designed to have 1.4 acres of pervious pavement and 0.6 acres of impervious pavement. The weighted coefficient of runoff can be calculated by:

Weighted coefficient of runoff (C) = ((Impervious area * 0.95) + (Pervious area * 0.8)) / total area

C = ((1.4 * 0.95) + (0.6 * 0.8)) / 2 = 0.845

The treatment volume required can then be calculated.

	Equation	Treatment Required
District	2 acres * 0.5 inch * conversion	3,630 cubic feet
County	2 acres * C * 1 inch * conversion	6,135 cubic feet

* Conversion from acre-inches to cubic feet = 43,560 (square feet/ acre)/ 12 (inch/foot) = 3,630

- *Step 2* – Treatment Volume Provided

	Equation	Answer
Step 2a – Pavement Section Storage (S in inches)	(Pavement Thickness * void space) + (Reservoir Layer Thickness * void space)	(4” * 0.20) + (6” * 0.25) = 2.3 inches
Step 2b – Total Volume Available	Pervious Area * S * Conversion	1.4 * 2.3 * 3,600 = 11,688 cubic feet
Step 2c – Site Specific 72 hour Drawdown Volume available	% available at 72 hours * Total Volume	50% * 11,688 = 5,844 cubic feet

A site specific groundwater mounding analysis must be provided to demonstrate that the water quality treatment volume recovers within 72 hours. If the system does not fully recover within 72 hours then the treatment volume provided must be revised to equal the volume that has been demonstrated to recover within 72 hours. For this example with the SHWT 18 inches below the existing grade, the site is in a B/D Soil Group and for clarification purposes of step 2c of this example it will be assumed that a drawdown analysis of the site would demonstrate that approximately 50% of the total volume available within 72 hours. Therefore only 50% of the Total Volume Available can be used in the treatment volume provided.

- *Step 3* – Additional Treatment Volume Required

	District	County
Treatment Required	3,630 cubic feet	6,135 cubic feet
Treatment Provided	5,844 cubic feet	5,844 cubic feet
Additional Treatment Required	3,630 - 5,844 < 0 No addition treatment required	6,135 - 5,844 = 291 cubic feet

Since the 72 hour drawdown analysis demonstrates that there is more treatment volume provided then is required under the ERP "presumptive" criteria based on the criteria in the Basis of Review for online systems utilizing retention there would be no additional treatment required to meet the ERP criteria.

To meet the requirement of Sarasota County's Land Development Regulations the design would either have to be adjusted to demonstrate the full treatment volume required would be available within 72 hours or the additional treatment volume required would have to be accommodated in an onsite downstream stormwater management system.

4.2.3 Stormwater Harvesting

Stormwater Harvesting is a LID Technique that is dependent on a number of site specific characteristics. This technique can be designed to be consistent with ERP Basis of Review and the Southwest Florida Management District's Water Use Permit requirements. It is recommended for the applicant to make the design decisions regarding their site specific characteristics and development goals. If these decisions include an option that would use Stormwater Harvesting for its ability to supply irrigation water and/or to meet other water demands then it is recommended to discuss the applicability of using the proposed Stormwater Harvesting System to meet part or all of the Stormwater Treatment requirements for the site during a pre-application with Sarasota County and the District.

4.2.4 Greenroof Stormwater Treatment Systems

Stormwater treatment systems incorporating Green Roof Treatment does not meet the requirements under ERP "presumptive" criteria based on the criteria in the Basis of Review. It is possible to receive an ERP permit using this type of system by demonstrating the proposed system meets an overall 80% (95% for direct discharges to Outstanding Florida Waters) Annual Pollutant Load Reduction. If it can be demonstrated that the Green Roof System meets the full 80% (95%) Annual Pollutant Load Reduction then the runoff from the area of the Green Roof can be removed from the calculations when determine the overall site treatment requirements. If the Green Roof System is not designed to meet the full 80% (95%) Annual Pollutant Load Reduction the applicant must demonstrate the portion of the annual pollutant load that is not treated in the Green Roof System can be accounted for through the remainder of the downstream "treatment train". However since the ERP Basis of Review only recognizes this LID Technique for its Annual Pollutant Load Reduction it would require that the downstream stormwater management system calculations use the same Annual Pollutant Load Reduction approach and it must be demonstrated that the "treatment train" as an overall stormwater management system meets an overall 80% (95% for direct discharges to Outstanding Florida Waters) Annual Pollutant Load Reduction.

The applicant may instead choose to apply a volume based calculations to account for the Treatment Volume Required difference between Sarasota County Land Development Regulation's of the runoff from the first 1 inch of rainfall and the ERP Basis of Review requirement of the volume from the first half inch of rainfall. If this approach is selected the applicant must design the Green Roof System consistent with the design criteria called out in section 3.4 and the cistern must be sufficiently sized to capture 50% of the Annual Rainfall using Figure 3.4-6. If these minimum design criteria are met it will be assumed that the difference in treatment volume required has been met for the green roof area and the volume from 0.5" of rainfall over the green roof area must be added to the treatment volume required from the contributing drainage area draining into the next downstream onsite stormwater management system.

4.2.5 Rainwater Harvesting

Stormwater treatment systems incorporating Rainwater Harvesting Treatment does not meet the requirements under ERP "presumptive" criteria based on the criteria in the Basis of Review. It is possible to receive an ERP permit using this type of system by demonstrating the proposed system meets an overall 80% (95% for direct discharges to Outstanding Florida Waters) Annual Pollutant Load Reduction. If it can be demonstrated that the Rainwater Harvesting System meets the full 80% (95%) Annual Pollutant Load Reduction then the runoff from the roof area being directed to the cistern can be removed from the calculations when determine the overall site treatment requirements. If the Rainwater Harvesting System is not designed to meet the full 80% (95%) Annual Pollutant Load Reduction the applicant must demonstrate the portion of the annual pollutant load that is not treated in the Rainwater Harvesting System can be accounted for through the remainder of the downstream "treatment train". However since the ERP Basis of Review only recognizes this LID Technique for its Annual Pollutant Load Reduction it would require that the downstream stormwater management system calculations use the same Annual Pollutant Load Reduction approach and it must be demonstrated that the "treatment train" as an overall stormwater management system meets an overall 80% (95% for direct discharges to Outstanding Florida Waters) Annual Pollutant Load Reduction.

The applicant may instead choose to apply a volume based calculations to account for the Treatment Volume Required difference between Sarasota County Land Development Regulation's of the runoff from the first 1 inch of rainfall and the ERP Basis of Review requirement of the volume from the first half inch of rainfall. If this approach is selected the applicant must design the Rainwater Harvesting System consistent with the design criteria called out in section 3.5 and the cistern must be sufficiently sized to capture 50% of the Annual Rainfall using Figure 3.5-4. If these minimum design criteria are met it will be assumed that the difference in treatment volume required has been met for the green roof area and the volume from 0.5" of rainfall over the green roof area must be added to the treatment volume required from the contributing drainage area draining into the next downstream onsite stormwater management system.

4.2.6 Detention with Biofiltration

A stormwater treatment system incorporating detention with biofiltration, as described in Section 3.6 of this Manual, do not meet the criteria for effluent filtration systems in Section 5.2(b) of the ERP Basis of Review. Systems incorporating these types of systems may still be used, however, to meet Sarasota County treatment requirements in addition to that required under ERP rules.

Assuming the same site parameters used in the design example for Detention with Biofiltration (Section 3.6). The site area is equal to 1 acre of impervious pavement plus an 80' x 30' (with 4:1 side slopes) Detention with Biofiltration system (approximately 0.06 ac) or a total site area of approximately 1.06 acres. For this example the BMP is assumed to be designed to meet all of the design criteria called out in Section 3.1 of this manual.

- *Step 1* – Calculate the treatment volume required

  The Coefficient of Runoff (C) = [(impervious area *.95) + (pervious area *.2)]/Area = [(1.06 acres * .95) + (0 acres * .2)]/1.06 acres = .95

	Equation	Treatment Required
District	1.06 acres * 0.5 inch * conversion	1,924 (cubic feet)
County	1.06 acres * 9.5 * 1 inch * conversion	3,655 (cubic feet)
Difference	County – District	1,131 (cubic feet)

  * Conversion = 43,560 (square feet/ acre)/ 12 (inch/foot)

- *Step 2* – Calculate the treatment volume provided

  To calculate the volume in the system by using the average area methodology:

  The area at the top of bank = 80' x 30' = 2,400 square feet

The area at the bottom the storage area = [80’ – (2 x side slope)] x [30’ – (2 x side slope)] = 1,584 square feet

Volume = (Top area + Bottom area)/2 * storage depth = (2,400 square feet + 1,584 square feet)/2 * 1 ft = 1,992 cubic feet.

- *Step 3* – Calculate the additional treatment volume required

  Additional treatment required = the treatment required difference – the treatment provide + the treatment volume required from the first 0.5” of rainfall.
  For this example the treatment volume provided is greater than the difference between the District and County treatment required therefore only the volume from the 0.5” of rainfall must be accounted for in an onsite downstream stormwater management system.

4.3 MAINTENANCE

LID Techniques presented in this Manual provide for optional designs of Stormwater Management Systems. The operation and maintenance of the LID Techniques is also addressed in this Manual. The applicant should be aware of the recommended maintenance schedules and requirements of the LID Techniques designed for the site specific project. It is important that any Stormwater Management System be maintained to provide for a reasonable assurance that the system function as designed. A LID System that is properly maintained will continue to function as designed and will be able to be recertified to be consistent with any Permit requirements.

APPENDIX A RAINFALL AND RUNOFF DATA

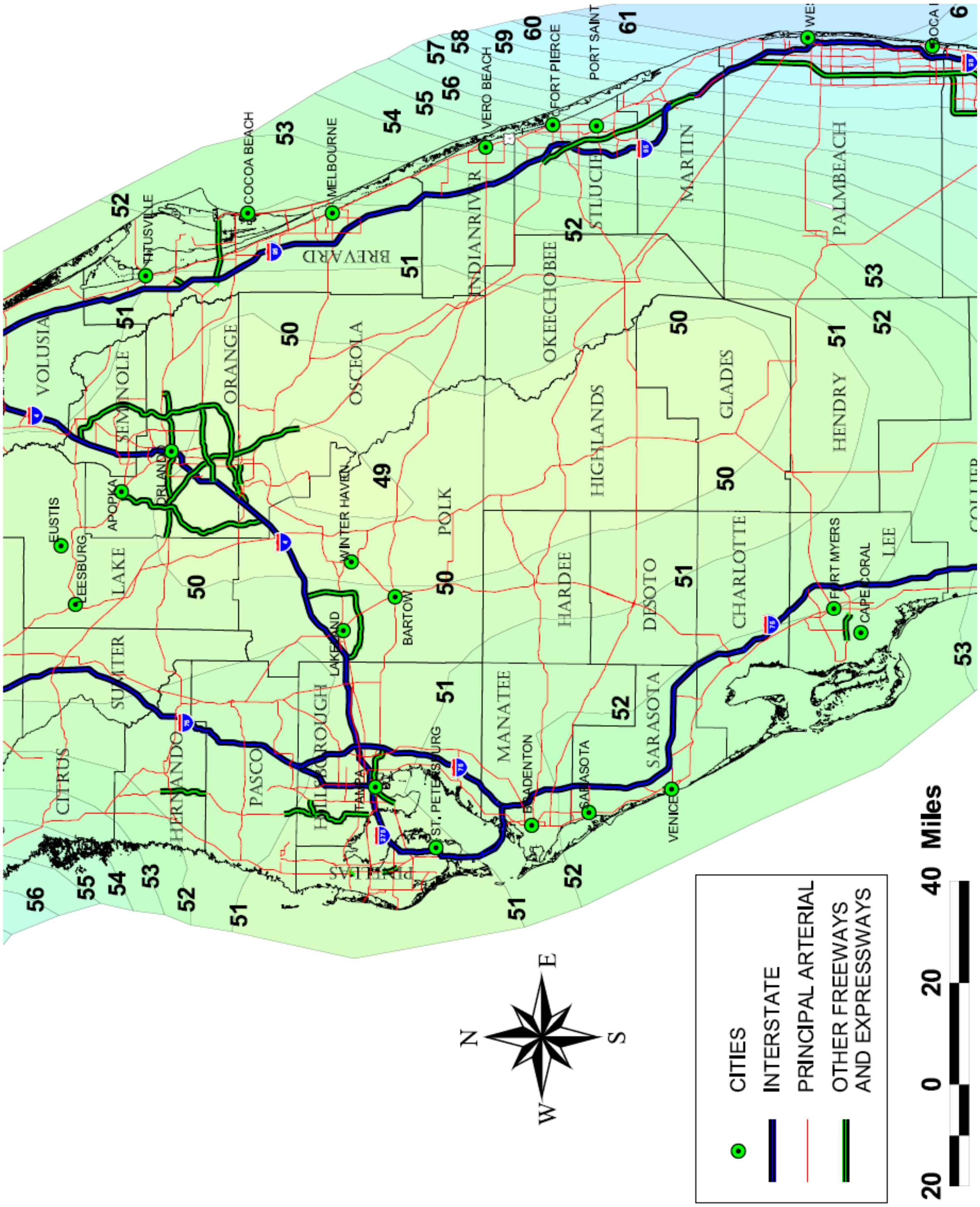

Figure A-1 Average Annual Rainfall Data for Sarasota and Vicinity

(Source FDEP, SO108, June 2007)

Zone 4
Mean Annual Runoff Coefficients (C Values) as a Function
of DCIA Percentage and Non-DCIA Curve Number (CN)

NDCIA	Percent DCIA																				
CN	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.004	0.045	0.086	0.127	0.168	0.209	0.250	0.291	0.332	0.373	0.414	0.455	0.496	0.536	0.577	0.618	0.659	0.700	0.741	0.782	0.823
35	0.007	0.048	0.089	0.129	0.170	0.211	0.252	0.293	0.333	0.374	0.415	0.456	0.497	0.537	0.578	0.619	0.660	0.701	0.741	0.782	0.823
40	0.011	0.051	0.092	0.133	0.173	0.214	0.254	0.295	0.336	0.376	0.417	0.458	0.498	0.539	0.579	0.620	0.661	0.701	0.742	0.782	0.823
45	0.016	0.056	0.096	0.137	0.177	0.217	0.258	0.298	0.339	0.379	0.419	0.460	0.500	0.540	0.581	0.621	0.662	0.702	0.742	0.783	0.823
50	0.022	0.062	0.102	0.142	0.182	0.222	0.262	0.302	0.342	0.382	0.423	0.463	0.503	0.543	0.583	0.623	0.663	0.703	0.743	0.783	0.823
55	0.030	0.070	0.109	0.149	0.189	0.228	0.268	0.308	0.347	0.387	0.427	0.466	0.506	0.546	0.585	0.625	0.664	0.704	0.744	0.783	0.823
60	0.040	0.080	0.119	0.158	0.197	0.236	0.275	0.314	0.353	0.393	0.432	0.471	0.510	0.549	0.588	0.627	0.667	0.706	0.745	0.784	0.823
65	0.054	0.092	0.131	0.169	0.208	0.246	0.285	0.323	0.362	0.400	0.438	0.477	0.515	0.554	0.592	0.631	0.669	0.708	0.746	0.785	0.823
70	0.071	0.109	0.147	0.184	0.222	0.259	0.297	0.335	0.372	0.410	0.447	0.485	0.522	0.560	0.598	0.635	0.673	0.710	0.748	0.785	0.823
75	0.096	0.132	0.168	0.205	0.241	0.277	0.314	0.350	0.387	0.423	0.459	0.496	0.532	0.568	0.605	0.641	0.678	0.714	0.750	0.787	0.823
80	0.130	0.165	0.199	0.234	0.268	0.303	0.338	0.372	0.407	0.442	0.476	0.511	0.546	0.580	0.615	0.650	0.684	0.719	0.754	0.788	0.823
85	0.182	0.214	0.246	0.278	0.310	0.342	0.374	0.406	0.438	0.470	0.502	0.534	0.566	0.599	0.631	0.663	0.695	0.727	0.759	0.791	0.823
90	0.266	0.294	0.322	0.350	0.378	0.406	0.433	0.461	0.489	0.517	0.545	0.573	0.600	0.628	0.656	0.684	0.712	0.740	0.767	0.795	0.823
95	0.429	0.449	0.469	0.488	0.508	0.528	0.547	0.567	0.587	0.606	0.626	0.646	0.665	0.685	0.705	0.725	0.744	0.764	0.784	0.803	0.823
98	0.616	0.626	0.636	0.647	0.657	0.667	0.678	0.688	0.699	0.709	0.719	0.730	0.740	0.750	0.761	0.771	0.782	0.792	0.802	0.813	0.823

Table A-1 Mean Annual Runoff Coefficient as a Function of DCIA and Pervious CN

(Source FDEP, SO108, June 2007)

Calculated Dry Retention Depth
For an Annual Mass Removal Efficiency of 85 Percent
Coastal (Zone 4)

NDCIA	Percent DCIA																	
CN	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.25	0.36	0.45	0.51	0.62	0.71	0.79	0.90	0.98	1.08	1.17	1.26	1.36	1.45	1.54	1.64	1.73	1.82	1.91
35	0.28	0.39	0.46	0.54	0.64	0.72	0.81	0.91	0.99	1.09	1.18	1.27	1.36	1.45	1.54	1.64	1.73	1.82	1.91
40	0.35	0.43	0.48	0.57	0.66	0.74	0.83	0.92	1.01	1.10	1.19	1.28	1.37	1.46	1.55	1.64	1.73	1.82	1.91
45	0.45	0.47	0.53	0.61	0.69	0.77	0.86	0.94	1.03	1.12	1.21	1.29	1.38	1.47	1.56	1.65	1.74	1.83	1.91
50	0.58	0.55	0.59	0.66	0.73	0.81	0.89	0.97	1.05	1.14	1.22	1.31	1.40	1.48	1.57	1.66	1.74	1.83	1.91
55	0.74	0.67	0.69	0.73	0.79	0.86	0.94	1.01	1.09	1.17	1.25	1.33	1.42	1.50	1.58	1.66	1.75	1.83	1.91
60	0.92	0.82	0.80	0.82	0.87	0.93	0.99	1.06	1.13	1.21	1.28	1.36	1.44	1.51	1.59	1.67	1.75	1.83	1.91
65	1.10	0.99	0.95	0.95	0.97	1.01	1.06	1.12	1.19	1.25	1.32	1.39	1.46	1.54	1.61	1.69	1.76	1.84	1.91
70	1.28	1.16	1.10	1.09	1.09	1.12	1.16	1.20	1.25	1.31	1.37	1.44	1.50	1.57	1.64	1.70	1.77	1.84	1.91
75	1.45	1.34	1.27	1.24	1.24	1.25	1.27	1.30	1.34	1.39	1.44	1.49	1.55	1.61	1.67	1.73	1.79	1.85	1.91
80	1.60	1.50	1.44	1.41	1.39	1.39	1.41	1.43	1.45	1.48	1.52	1.56	1.61	1.65	1.70	1.75	1.81	1.86	1.91
85	1.73	1.66	1.61	1.58	1.56	1.55	1.55	1.56	1.57	1.59	1.62	1.65	1.68	1.71	1.75	1.79	1.83	1.87	1.91
90	1.84	1.79	1.76	1.73	1.72	1.71	1.70	1.70	1.71	1.72	1.73	1.74	1.76	1.78	1.81	1.83	1.86	1.89	1.91
95	1.91	1.89	1.88	1.87	1.86	1.85	1.85	1.84	1.84	1.85	1.85	1.85	1.86	1.86	1.87	1.88	1.89	1.90	1.91
98	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.91	1.91	1.91	1.91

Table A-2 Calculated Dry Retention Depth as a Function of DCIA and Pervious CN
(Source FDEP, Draft Stormwater Quality Applicant's Handbook, July 2009)

Mean Annual Mass Removal Efficiencies for 0.25-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	90.10	86.60	79.20	71.40	64.50	58.60	53.50	49.20	45.50	42.30	39.50	37.10	34.90	33.00	31.30	29.70	28.30	27.10	25.90	24.80
35.0	86.20	84.30	77.80	70.50	63.90	58.20	53.20	49.00	45.30	42.20	39.40	37.00	34.90	33.00	31.20	29.70	28.30	27.00	25.90	24.80
40.0	81.60	81.50	75.90	69.30	63.10	57.60	52.80	48.70	45.10	42.00	39.30	36.90	34.80	32.90	31.20	29.70	28.30	27.00	25.90	24.80
45.0	76.50	78.10	73.70	67.80	62.00	56.80	52.20	48.20	44.80	41.80	39.10	36.80	34.70	32.80	31.10	29.60	28.30	27.00	25.90	24.80
50.0	71.00	74.20	71.00	65.90	60.70	55.80	51.50	47.70	44.40	41.40	38.90	36.60	34.50	32.70	31.10	29.60	28.20	27.00	25.90	24.80
55.0	65.30	69.90	67.90	63.70	59.10	54.70	50.60	47.00	43.80	41.10	38.50	36.30	34.40	32.60	31.00	29.50	28.20	27.00	25.80	24.80
60.0	59.70	65.20	64.40	61.20	57.20	53.20	49.60	46.20	43.20	40.60	38.20	36.10	34.10	32.40	30.80	29.40	28.10	26.90	25.80	24.80
65.0	54.20	60.20	60.50	58.20	55.00	51.50	48.20	45.20	42.40	39.90	37.70	35.70	33.80	32.20	30.70	29.30	28.00	26.90	25.80	24.80
70.0	49.10	54.90	56.10	54.70	52.30	49.40	46.60	43.90	41.40	39.20	37.10	35.20	33.50	31.90	30.50	29.10	27.90	26.80	25.80	24.80
75.0	44.30	49.40	51.10	50.70	49.10	46.90	44.60	42.30	40.10	38.10	36.30	34.60	33.00	31.50	30.20	28.90	27.80	26.70	25.70	24.80
80.0	40.00	44.10	45.80	46.00	45.20	43.70	42.00	40.20	38.50	36.80	35.20	33.70	32.30	31.00	29.80	28.70	27.60	26.60	25.70	24.80
85.0	36.20	38.90	40.40	40.80	40.60	39.80	38.80	37.50	36.30	35.00	33.70	32.50	31.40	30.20	29.20	28.20	27.30	26.40	25.60	24.80
90.0	32.80	34.20	35.00	35.40	35.40	35.10	34.60	33.90	33.20	32.40	31.60	30.80	29.90	29.10	28.30	27.60	26.90	26.10	25.50	24.80
95.0	29.30	29.70	29.90	30.00	29.90	29.80	29.70	29.40	29.10	28.80	28.50	28.10	27.70	27.30	26.90	26.50	26.10	25.60	25.20	24.80
98.0	27.20	27.20	27.20	27.10	27.00	27.00	26.80	26.70	26.60	26.50	26.30	26.20	26.00	25.90	25.70	25.50	25.40	25.20	25.00	24.80

Mean Annual Mass Removal Efficiencies for 0.50-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	94.00	94.20	92.10	88.80	84.80	80.50	76.30	72.40	68.60	65.20	62.00	59.10	56.40	53.90	51.70	49.50	47.60	45.80	44.10	42.60
35.0	91.10	92.30	90.70	87.70	84.00	79.90	75.90	72.00	68.40	65.00	61.90	59.00	56.30	53.90	51.60	49.50	47.60	45.80	44.10	42.60
40.0	87.80	90.00	88.90	86.40	82.90	79.10	75.30	71.50	68.00	64.70	61.60	58.80	56.20	53.80	51.50	49.40	47.50	45.70	44.10	42.60
45.0	84.00	87.20	86.80	84.70	81.60	78.10	74.50	70.90	67.50	64.30	61.30	58.60	56.00	53.60	51.40	49.40	47.50	45.70	44.10	42.60
50.0	79.90	84.00	84.30	82.70	80.10	76.90	73.50	70.20	66.90	63.90	61.00	58.30	55.80	53.50	51.30	49.30	47.40	45.70	44.10	42.60
55.0	75.60	80.40	81.40	80.40	78.20	75.40	72.30	69.20	66.20	63.30	60.50	57.90	55.50	53.20	51.10	49.20	47.30	45.60	44.00	42.60
60.0	71.30	76.50	78.10	77.60	75.90	73.60	70.90	68.00	65.20	62.50	59.90	57.40	55.10	53.00	50.90	49.00	47.20	45.60	44.00	42.60
65.0	67.10	72.40	74.40	74.50	73.30	71.40	69.10	66.60	64.10	61.60	59.20	56.90	54.70	52.60	50.60	48.80	47.10	45.50	44.00	42.60
70.0	63.00	68.10	70.30	70.80	70.20	68.90	67.00	64.90	62.70	60.50	58.30	56.10	54.10	52.10	50.30	48.60	46.90	45.40	43.90	42.60
75.0	59.20	63.70	65.90	66.70	66.60	65.70	64.40	62.70	60.90	59.00	57.10	55.20	53.30	51.50	49.80	48.20	46.70	45.20	43.80	42.60
80.0	55.80	59.40	61.40	62.30	62.40	61.90	61.10	59.90	58.60	57.10	55.50	53.90	52.30	50.70	49.20	47.80	46.40	45.00	43.80	42.60
85.0	52.70	55.20	56.70	57.50	57.70	57.60	57.10	56.40	55.50	54.50	53.30	52.10	50.80	49.60	48.30	47.10	45.90	44.70	43.60	42.60
90.0	49.70	51.10	52.00	52.50	52.80	52.80	52.60	52.20	51.70	51.10	50.30	49.60	48.70	47.90	47.00	46.10	45.20	44.30	43.40	42.60
95.0	46.70	47.10	47.40	47.50	47.60	47.60	47.50	47.30	47.10	46.80	46.50	46.20	45.80	45.40	44.90	44.50	44.00	43.50	43.00	42.60
98.0	44.90	44.90	44.80	44.80	44.70	44.70	44.60	44.50	44.30	44.20	44.10	44.00	43.80	43.60	43.50	43.30	43.10	42.90	42.70	42.60

Mean Annual Mass Removal Efficiencies for 0.75-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	95.60	96.40	95.60	94.10	92.10	89.60	86.80	83.90	81.00	78.10	75.30	72.70	70.10	67.70	65.40	63.30	61.20	59.30	57.40	55.70
35.0	93.50	94.90	94.50	93.20	91.30	89.00	86.30	83.50	80.70	77.90	75.10	72.50	70.00	67.60	65.40	63.20	61.20	59.30	57.40	55.70
40.0	91.00	93.10	93.00	92.00	90.30	88.10	85.70	83.00	80.20	77.50	74.90	72.30	69.80	67.50	65.30	63.10	61.10	59.20	57.40	55.70
45.0	88.10	90.90	91.30	90.50	89.10	87.10	84.80	82.30	79.70	77.10	74.50	72.00	69.60	67.30	65.10	63.00	61.10	59.20	57.40	55.70
50.0	85.00	88.40	89.20	88.80	87.60	85.90	83.80	81.50	79.00	76.50	74.10	71.70	69.30	67.10	65.00	62.90	61.00	59.10	57.40	55.70
55.0	81.70	85.70	86.80	86.80	85.90	84.50	82.60	80.50	78.20	75.90	73.50	71.20	69.00	66.80	64.80	62.80	60.90	59.10	57.40	55.70
60.0	78.40	82.60	84.10	84.40	83.90	82.70	81.10	79.20	77.20	75.00	72.80	70.70	68.60	66.50	64.50	62.60	60.80	59.00	57.30	55.70
65.0	75.00	79.30	81.10	81.70	81.50	80.70	79.40	77.80	76.00	74.00	72.00	70.00	68.00	66.10	64.20	62.30	60.60	58.90	57.30	55.70
70.0	71.70	75.90	77.90	78.70	78.70	78.20	77.30	76.00	74.40	72.70	71.00	69.10	67.30	65.50	63.80	62.00	60.40	58.80	57.20	55.70
75.0	68.70	72.50	74.40	75.40	75.60	75.30	74.70	73.70	72.50	71.10	69.60	68.00	66.40	64.80	63.20	61.60	60.10	58.60	57.10	55.70
80.0	65.90	69.00	70.80	71.70	72.10	72.10	71.70	71.00	70.10	69.00	67.80	66.60	65.20	63.90	62.50	61.10	59.70	58.30	57.00	55.70
85.0	63.50	65.70	67.10	67.90	68.30	68.30	68.10	67.70	67.10	66.40	65.50	64.60	63.60	62.50	61.40	60.30	59.10	58.00	56.80	55.70
90.0	61.20	62.40	63.20	63.80	64.10	64.20	64.10	63.90	63.60	63.20	62.70	62.10	61.40	60.70	59.90	59.10	58.30	57.40	56.60	55.70
95.0	58.70	59.10	59.40	59.60	59.70	59.70	59.70	59.70	59.50	59.40	59.10	58.90	58.60	58.20	57.90	57.50	57.10	56.60	56.20	55.70
98.0	57.50	57.50	57.50	57.50	57.50	57.40	57.40	57.30	57.20	57.10	57.00	56.90	56.80	56.60	56.50	56.40	56.20	56.00	55.90	55.70

Mean Annual Mass Removal Efficiencies for 1.00-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	96.60	97.50	97.20	96.40	95.20	93.70	91.90	90.00	87.90	85.70	83.50	81.20	79.00	76.90	74.80	72.80	70.90	69.10	67.30	65.60
35.0	95.00	96.30	96.20	95.60	94.50	93.10	91.40	89.60	87.50	85.40	83.20	81.10	78.90	76.80	74.80	72.80	70.90	69.00	67.20	65.60
40.0	93.00	94.90	95.10	94.60	93.60	92.40	90.80	89.00	87.10	85.10	82.90	80.80	78.70	76.70	74.70	72.70	70.80	69.00	67.20	65.60
45.0	90.80	93.10	93.60	93.40	92.60	91.50	90.00	88.40	86.50	84.60	82.60	80.50	78.50	76.50	74.50	72.60	70.70	68.90	67.20	65.60
50.0	88.30	91.10	92.00	91.90	91.40	90.40	89.10	87.60	85.90	84.00	82.10	80.10	78.20	76.20	74.30	72.50	70.60	68.90	67.20	65.60
55.0	85.70	89.00	90.10	90.20	89.90	89.10	88.00	86.60	85.10	83.40	81.50	79.70	77.80	75.90	74.10	72.30	70.50	68.80	67.10	65.60
60.0	83.10	86.60	87.90	88.30	88.10	87.60	86.70	85.50	84.10	82.50	80.80	79.10	77.30	75.60	73.80	72.10	70.40	68.70	67.10	65.60
65.0	80.40	83.90	85.50	86.10	86.10	85.80	85.10	84.10	82.90	81.50	80.00	78.40	76.80	75.10	73.50	71.80	70.20	68.60	67.10	65.60
70.0	77.70	81.20	82.80	83.60	83.90	83.70	83.20	82.40	81.40	80.30	78.90	77.50	76.00	74.50	73.00	71.50	70.00	68.50	67.00	65.60
75.0	75.20	78.40	80.10	81.00	81.30	81.30	81.00	80.40	79.60	78.70	77.60	76.40	75.10	73.80	72.40	71.00	69.60	68.30	66.90	65.60
80.0	73.00	75.60	77.20	78.10	78.50	78.60	78.40	78.10	77.50	76.80	75.90	74.90	73.90	72.80	71.60	70.40	69.20	68.00	66.80	65.60
85.0	71.10	73.00	74.20	75.00	75.40	75.60	75.50	75.30	74.90	74.40	73.80	73.10	72.30	71.40	70.50	69.60	68.60	67.60	66.60	65.60
90.0	69.40	70.50	71.20	71.70	72.00	72.20	72.20	72.10	71.90	71.60	71.20	70.80	70.30	69.70	69.10	68.50	67.80	67.10	66.30	65.60
95.0	67.60	67.90	68.10	68.30	68.40	68.50	68.50	68.50	68.40	68.30	68.20	68.00	67.80	67.60	67.30	67.00	66.70	66.30	65.90	65.60
98.0	66.70	66.80	66.80	66.80	66.80	66.70	66.70	66.70	66.60	66.60	66.50	66.40	66.30	66.30	66.10	66.00	65.90	65.80	65.70	65.60

Table A-3 Mean Annual Mass Removal Efficiencies for Zone 4

Mean Annual Mass Removal Efficiencies for 1.25-inches of Retention for Zone 4																				
NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	97.30	98.00	98.00	97.50	96.80	95.80	94.60	93.30	91.80	90.20	88.50	86.80	85.00	83.20	81.40	79.60	77.90	76.20	74.50	72.90
35.0	95.90	97.20	97.30	96.90	96.20	95.30	94.20	92.90	91.50	89.90	88.30	86.60	84.80	83.00	81.30	79.50	77.80	76.20	74.50	72.90
40.0	94.50	96.00	96.30	96.10	95.50	94.60	93.60	92.40	91.10	89.60	88.00	86.30	84.60	82.90	81.20	79.50	77.80	76.10	74.50	72.90
45.0	92.70	94.60	95.10	95.00	94.60	93.90	93.00	91.80	90.60	89.10	87.60	86.00	84.40	82.70	81.00	79.30	77.70	76.10	74.50	72.90
50.0	90.70	93.10	93.80	93.80	93.60	93.00	92.10	91.10	89.90	88.60	87.20	85.70	84.10	82.40	80.80	79.20	77.60	76.00	74.50	72.90
55.0	88.60	91.30	92.20	92.50	92.30	91.90	91.20	90.30	89.20	88.00	86.60	85.20	83.70	82.10	80.60	79.00	77.50	75.90	74.40	72.90
60.0	86.40	89.30	90.50	90.90	90.90	90.60	90.00	89.20	88.30	87.20	86.00	84.60	83.20	81.80	80.30	78.80	77.30	75.80	74.40	72.90
65.0	84.30	87.20	88.50	89.10	89.20	89.00	88.60	88.00	87.20	86.30	85.20	84.00	82.70	81.30	79.90	78.50	77.10	75.70	74.30	72.90
70.0	82.10	85.00	86.40	87.10	87.40	87.30	87.00	86.60	85.90	85.10	84.20	83.10	82.00	80.70	79.50	78.20	76.90	75.60	74.30	72.90
75.0	80.10	82.70	84.10	84.90	85.30	85.40	85.20	84.90	84.40	83.70	82.90	82.00	81.10	80.00	78.90	77.70	76.60	75.40	74.20	72.90
80.0	78.20	80.40	81.70	82.50	83.00	83.20	83.10	82.90	82.50	82.00	81.40	80.70	79.90	79.10	78.10	77.10	76.10	75.10	74.00	72.90
85.0	76.70	78.30	79.30	80.10	80.50	80.70	80.70	80.60	80.40	80.10	79.60	79.10	78.50	77.80	77.10	76.40	75.50	74.70	73.80	72.90
90.0	75.40	76.30	77.00	77.50	77.80	78.00	78.10	78.00	77.90	77.70	77.50	77.10	76.80	76.30	75.90	75.30	74.80	74.20	73.60	72.90
95.0	74.20	74.50	74.70	74.90	75.00	75.10	75.10	75.10	75.10	75.00	74.90	74.80	74.60	74.50	74.30	74.00	73.80	73.50	73.30	72.90
98.0	73.70	73.70	73.70	73.70	73.70	73.70	73.70	73.70	73.70	73.60	73.60	73.60	73.50	73.40	73.40	73.30	73.20	73.10	73.00	72.90

Mean Annual Mass Removal Efficiencies for 1.50-inches of Retention for Zone 4																				
NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	97.80	98.40	98.50	98.20	97.70	97.10	96.20	95.30	94.20	93.00	91.70	90.40	89.00	87.50	86.00	84.50	83.00	81.50	80.00	78.50
35.0	96.70	97.70	97.90	97.70	97.30	96.60	95.80	94.90	93.90	92.80	91.50	90.20	88.80	87.40	85.90	84.40	82.90	81.40	80.00	78.50
40.0	95.50	96.80	97.10	97.00	96.60	96.10	95.40	94.50	93.50	92.40	91.20	89.90	88.60	87.20	85.80	84.30	82.90	81.40	80.00	78.50
45.0	94.10	95.70	96.20	96.20	95.90	95.40	94.80	94.00	93.10	92.00	90.90	89.70	88.40	87.00	85.60	84.20	82.80	81.30	79.90	78.50
50.0	92.50	94.40	95.10	95.20	95.00	94.60	94.10	93.30	92.50	91.50	90.50	89.30	88.10	86.80	85.40	84.10	82.70	81.30	79.90	78.50
55.0	90.80	93.00	93.80	94.00	94.00	93.70	93.20	92.60	91.80	91.00	90.00	88.90	87.70	86.50	85.20	83.90	82.50	81.20	79.90	78.50
60.0	88.90	91.30	92.30	92.70	92.80	92.60	92.20	91.70	91.00	90.30	89.40	88.40	87.30	86.10	84.90	83.70	82.40	81.10	79.80	78.50
65.0	87.10	89.60	90.70	91.30	91.40	91.30	91.10	90.60	90.10	89.40	88.60	87.70	86.80	85.70	84.60	83.40	82.20	81.00	79.80	78.50
70.0	85.40	87.80	89.00	89.60	89.90	89.90	89.70	89.40	89.00	88.40	87.70	87.00	86.10	85.10	84.10	83.10	82.00	80.80	79.70	78.50
75.0	83.80	85.90	87.10	87.80	88.20	88.30	88.20	88.00	87.70	87.20	86.70	86.00	85.30	84.40	83.60	82.60	81.60	80.60	79.60	78.50
80.0	82.20	84.00	85.20	85.90	86.30	86.40	86.50	86.40	86.20	85.80	85.40	84.90	84.30	83.60	82.90	82.10	81.20	80.40	79.50	78.50
85.0	81.00	82.30	83.20	83.80	84.20	84.40	84.50	84.50	84.40	84.20	83.90	83.50	83.00	82.50	82.00	81.40	80.70	80.00	79.30	78.50
90.0	80.00	80.70	81.30	81.80	82.10	82.30	82.40	82.40	82.40	82.20	82.10	81.80	81.60	81.20	80.90	80.50	80.00	79.60	79.10	78.50
95.0	79.10	79.40	79.60	79.80	79.90	80.00	80.10	80.10	80.10	80.10	80.00	79.90	79.80	79.70	79.60	79.40	79.20	79.00	78.80	78.50
98.0	79.00	79.00	79.00	79.10	79.10	79.10	79.10	79.10	79.00	79.00	79.00	79.00	78.90	78.90	78.80	78.80	78.70	78.70	78.60	78.50

Mean Annual Mass Removal Efficiencies for 1.75-inches of Retention for Zone 4																				
NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	98.20	98.70	98.80	98.70	98.40	97.90	97.30	96.50	95.70	94.80	93.80	92.80	91.70	90.50	89.30	88.00	86.70	85.40	84.10	82.80
35.0	97.30	98.10	98.30	98.20	97.90	97.50	96.90	96.20	95.50	94.60	93.60	92.60	91.50	90.40	89.20	87.90	86.70	85.40	84.10	82.80
40.0	96.20	97.40	97.70	97.70	97.40	97.00	96.50	95.90	95.10	94.30	93.40	92.40	91.30	90.20	89.00	87.80	86.60	85.40	84.10	82.80
45.0	95.10	96.50	96.90	97.00	96.80	96.50	96.00	95.40	94.70	93.90	93.10	92.10	91.10	90.00	88.90	87.70	86.50	85.30	84.10	82.80
50.0	93.90	95.50	96.00	96.10	96.00	95.80	95.40	94.80	94.20	93.50	92.70	91.80	90.80	89.80	88.70	87.60	86.40	85.20	84.00	82.80
55.0	92.40	94.30	95.00	95.20	95.20	95.00	94.60	94.20	93.60	93.00	92.20	91.40	90.50	89.50	88.50	87.40	86.30	85.20	84.00	82.80
60.0	90.90	92.90	93.70	94.10	94.20	94.00	93.80	93.40	92.90	92.40	91.70	90.90	90.10	89.20	88.20	87.20	86.20	85.10	83.90	82.80
65.0	89.40	91.40	92.40	92.90	93.00	93.00	92.80	92.50	92.10	91.60	91.00	90.40	89.60	88.80	87.90	87.00	86.00	84.90	83.90	82.80
70.0	87.90	89.90	90.90	91.50	91.70	91.80	91.70	91.50	91.20	90.70	90.30	89.70	89.00	88.30	87.50	86.60	85.70	84.80	83.80	82.80
75.0	86.50	88.40	89.40	90.00	90.30	90.50	90.40	90.30	90.10	89.70	89.30	88.90	88.30	87.70	87.00	86.20	85.40	84.60	83.70	82.80
80.0	85.30	86.80	87.80	88.40	88.80	88.90	89.00	88.90	88.80	88.60	88.30	87.90	87.40	86.90	86.40	85.70	85.10	84.40	83.60	82.80
85.0	84.30	85.40	86.20	86.70	87.10	87.30	87.40	87.40	87.30	87.20	87.00	86.70	86.40	86.00	85.60	85.10	84.60	84.00	83.40	82.80
90.0	83.50	84.10	84.70	85.00	85.30	85.50	85.70	85.70	85.70	85.60	85.50	85.40	85.20	84.90	84.70	84.40	84.00	83.70	83.30	82.80
95.0	82.90	83.20	83.40	83.60	83.70	83.80	83.90	83.90	83.90	83.90	83.90	83.80	83.80	83.70	83.60	83.50	83.30	83.20	83.00	82.80
98.0	83.00	83.10	83.10	83.10	83.10	83.10	83.20	83.20	83.20	83.10	83.10	83.10	83.10	83.10	83.00	83.00	83.00	82.90	82.90	82.80

Mean Annual Mass Removal Efficiencies for 2.00-inches of Retention for Zone 4																				
NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	98.50	99.00	99.10	99.00	98.70	98.40	98.00	97.40	96.80	96.10	95.30	94.50	93.60	92.60	91.60	90.60	89.50	88.40	87.30	86.10
35.0	97.80	98.50	98.60	98.60	98.40	98.10	97.70	97.10	96.50	95.90	95.10	94.30	93.40	92.50	91.50	90.50	89.40	88.40	87.30	86.10
40.0	96.90	97.80	98.10	98.10	98.00	97.70	97.30	96.80	96.20	95.60	94.90	94.10	93.30	92.40	91.40	90.40	89.40	88.30	87.20	86.10
45.0	95.90	97.10	97.50	97.60	97.50	97.20	96.80	96.40	95.90	95.30	94.60	93.80	93.00	92.20	91.30	90.30	89.30	88.30	87.20	86.10
50.0	94.90	96.30	96.70	96.90	96.80	96.60	96.30	95.90	95.40	94.90	94.20	93.60	92.80	92.00	91.10	90.20	89.20	88.20	87.20	86.10
55.0	93.70	95.30	95.90	96.10	96.10	95.90	95.70	95.30	94.90	94.40	93.80	93.20	92.50	91.70	90.90	90.00	89.10	88.10	87.10	86.10
60.0	92.50	94.10	94.90	95.10	95.20	95.10	95.00	94.70	94.30	93.90	93.40	92.80	92.10	91.40	90.60	89.80	88.90	88.00	87.10	86.10
65.0	91.20	92.90	93.70	94.10	94.30	94.30	94.10	93.90	93.60	93.20	92.80	92.30	91.70	91.00	90.30	89.60	88.80	87.90	87.10	86.10
70.0	89.90	91.60	92.50	92.90	93.20	93.20	93.20	93.00	92.80	92.50	92.10	91.70	91.20	90.60	90.00	89.30	88.60	87.80	87.00	86.10
75.0	88.70	90.20	91.20	91.70	92.00	92.10	92.10	92.00	91.90	91.60	91.30	91.00	90.50	90.10	89.50	88.90	88.30	87.60	86.90	86.10
80.0	87.70	89.00	89.80	90.30	90.70	90.90	90.90	90.90	90.80	90.60	90.40	90.10	89.80	89.40	89.00	88.50	88.00	87.40	86.80	86.10
85.0	86.90	87.80	88.50	89.00	89.30	89.50	89.60	89.60	89.60	89.50	89.40	89.20	88.90	88.70	88.30	88.00	87.60	87.10	86.60	86.10
90.0	86.30	86.80	87.30	87.60	87.90	88.00	88.20	88.20	88.30	88.20	88.20	88.10	87.90	87.80	87.60	87.30	87.10	86.80	86.50	86.10
95.0	85.90	86.10	86.30	86.50	86.60	86.70	86.80	86.80	86.80	86.90	86.90	86.80	86.80	86.80	86.70	86.60	86.50	86.40	86.30	86.10
98.0	86.10	86.20	86.20	86.20	86.30	86.30	86.30	86.30	86.30	86.30	86.30	86.30	86.30	86.30	86.30	86.20	86.20	86.20	86.20	86.10

Table A-3 Mean Annual Mass Removal Efficiencies for Zone 4

Mean Annual Mass Removal Efficiencies for 2.25-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	98.80	99.20	99.20	99.20	99.00	98.80	98.40	98.00	97.50	97.00	96.30	95.70	94.90	94.20	93.30	92.50	91.60	90.60	89.70	88.70
35.0	98.10	98.70	98.90	98.80	98.70	98.50	98.20	97.80	97.30	96.80	96.20	95.50	94.80	94.00	93.20	92.40	91.50	90.60	89.70	88.70
40.0	97.40	98.20	98.40	98.50	98.40	98.20	97.90	97.50	97.00	96.50	96.00	95.30	94.60	93.90	93.10	92.30	91.50	90.60	89.60	88.70
45.0	96.50	97.60	97.90	98.00	97.90	97.80	97.50	97.10	96.70	96.20	95.70	95.10	94.40	93.70	93.00	92.20	91.40	90.50	89.60	88.70
50.0	95.70	96.90	97.30	97.40	97.40	97.30	97.00	96.70	96.30	95.90	95.40	94.80	94.20	93.60	92.80	92.10	91.30	90.50	89.60	88.70
55.0	94.80	96.10	96.60	96.80	96.80	96.70	96.50	96.20	95.90	95.50	95.00	94.50	94.00	93.30	92.70	91.90	91.20	90.40	89.60	88.70
60.0	93.70	95.10	95.70	96.00	96.00	96.00	95.90	95.60	95.40	95.00	94.60	94.10	93.60	93.10	92.40	91.80	91.10	90.30	89.50	88.70
65.0	92.60	94.10	94.80	95.10	95.20	95.20	95.20	95.00	94.70	94.40	94.10	93.70	93.20	92.70	92.20	91.60	90.90	90.20	89.50	88.70
70.0	91.50	92.90	93.70	94.10	94.30	94.40	94.30	94.20	94.00	93.80	93.50	93.20	92.80	92.30	91.80	91.30	90.70	90.10	89.40	88.70
75.0	90.50	91.80	92.60	93.00	93.30	93.40	93.40	93.40	93.30	93.10	92.80	92.60	92.20	91.90	91.40	91.00	90.50	89.90	89.30	88.70
80.0	89.60	90.70	91.40	91.90	92.20	92.30	92.40	92.40	92.40	92.30	92.10	91.90	91.60	91.30	91.00	90.60	90.20	89.70	89.20	88.70
85.0	88.90	89.70	90.30	90.70	91.00	91.20	91.30	91.40	91.40	91.30	91.20	91.10	90.90	90.70	90.40	90.10	89.80	89.50	89.10	88.70
90.0	88.40	89.00	89.30	89.60	89.90	90.00	90.10	90.20	90.20	90.20	90.20	90.10	90.10	89.90	89.80	89.60	89.40	89.20	89.00	88.70
95.0	88.20	88.40	88.60	88.70	88.90	89.00	89.00	89.10	89.10	89.20	89.20	89.20	89.10	89.10	89.10	89.00	89.00	88.90	88.80	88.70
98.0	88.60	88.60	88.60	88.70	88.70	88.70	88.70	88.80	88.80	88.80	88.80	88.80	88.80	88.80	88.80	88.80	88.80	88.70	88.70	88.70

Mean Annual Mass Removal Efficiencies for 2.50-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.00	99.30	99.40	99.30	99.20	99.00	98.80	98.50	98.10	97.60	97.10	96.60	95.90	95.30	94.60	93.90	93.10	92.40	91.50	90.70
35.0	98.40	98.90	99.10	99.10	99.00	98.80	98.60	98.30	97.90	97.40	96.90	96.40	95.80	95.20	94.50	93.80	93.10	92.30	91.50	90.70
40.0	97.80	98.50	98.70	98.70	98.70	98.50	98.30	98.00	97.60	97.20	96.80	96.20	95.70	95.10	94.40	93.80	93.00	92.30	91.50	90.70
45.0	97.10	98.00	98.20	98.30	98.30	98.20	98.00	97.70	97.40	97.00	96.50	96.00	95.50	94.90	94.30	93.70	93.00	92.20	91.50	90.70
50.0	96.30	97.40	97.80	97.90	97.90	97.80	97.60	97.30	97.00	96.70	96.30	95.80	95.30	94.70	94.20	93.50	92.90	92.20	91.40	90.70
55.0	95.60	96.70	97.20	97.30	97.30	97.30	97.10	96.90	96.60	96.30	95.90	95.50	95.00	94.50	94.00	93.40	92.80	92.10	91.40	90.70
60.0	94.70	95.90	96.40	96.70	96.70	96.70	96.60	96.40	96.20	95.90	95.50	95.20	94.80	94.30	93.80	93.20	92.70	92.00	91.40	90.70
65.0	93.80	95.00	95.60	95.90	96.00	96.00	95.90	95.80	95.60	95.40	95.10	94.80	94.40	94.00	93.50	93.00	92.50	91.90	91.30	90.70
70.0	92.80	94.00	94.70	95.00	95.20	95.30	95.30	95.20	95.00	94.80	94.60	94.30	94.00	93.70	93.30	92.80	92.30	91.80	91.30	90.70
75.0	91.90	93.10	93.70	94.10	94.30	94.50	94.50	94.40	94.30	94.20	94.00	93.80	93.50	93.20	92.90	92.50	92.10	91.70	91.20	90.70
80.0	91.20	92.10	92.70	93.10	93.40	93.50	93.60	93.60	93.60	93.50	93.40	93.20	93.00	92.80	92.50	92.20	91.90	91.50	91.10	90.70
85.0	90.60	91.30	91.80	92.20	92.40	92.60	92.70	92.70	92.70	92.70	92.60	92.50	92.40	92.20	92.00	91.80	91.60	91.30	91.00	90.70
90.0	90.20	90.60	91.00	91.20	91.40	91.60	91.70	91.80	91.80	91.80	91.80	91.80	91.70	91.60	91.50	91.40	91.20	91.10	90.90	90.70
95.0	90.10	90.30	90.40	90.60	90.70	90.70	90.80	90.90	90.90	91.00	91.00	91.00	91.00	91.00	90.90	90.90	90.90	90.80	90.80	90.70
98.0	90.50	90.50	90.50	90.60	90.60	90.60	90.60	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70	90.70

Mean Annual Mass Removal Efficiencies for 2.75-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.10	99.40	99.50	99.50	99.40	99.20	99.00	98.80	98.50	98.10	97.70	97.20	96.70	96.20	95.60	95.00	94.30	93.70	93.00	92.30
35.0	98.70	99.10	99.20	99.20	99.20	99.00	98.90	98.60	98.30	98.00	97.50	97.10	96.60	96.10	95.50	94.90	94.30	93.60	93.00	92.30
40.0	98.10	98.70	98.90	98.90	98.90	98.80	98.60	98.40	98.10	97.80	97.40	96.90	96.50	96.00	95.40	94.90	94.20	93.60	92.90	92.30
45.0	97.60	98.30	98.50	98.60	98.60	98.50	98.30	98.10	97.90	97.50	97.20	96.80	96.30	95.80	95.30	94.80	94.20	93.60	92.90	92.30
50.0	96.90	97.80	98.10	98.20	98.20	98.10	98.00	97.80	97.60	97.30	96.90	96.60	96.10	95.70	95.20	94.70	94.10	93.50	92.90	92.30
55.0	96.20	97.20	97.60	97.70	97.80	97.70	97.60	97.40	97.20	96.90	96.60	96.30	95.90	95.50	95.00	94.50	94.00	93.50	92.90	92.30
60.0	95.50	96.60	97.00	97.20	97.30	97.20	97.10	97.00	96.80	96.60	96.30	96.00	95.60	95.30	94.80	94.40	93.90	93.40	92.80	92.30
65.0	94.70	95.80	96.30	96.50	96.60	96.70	96.60	96.50	96.30	96.10	95.90	95.60	95.30	95.00	94.60	94.20	93.80	93.30	92.80	92.30
70.0	93.90	95.00	95.50	95.80	96.00	96.00	96.00	95.90	95.80	95.70	95.50	95.20	95.00	94.70	94.40	94.00	93.60	93.20	92.70	92.30
75.0	93.10	94.10	94.70	95.00	95.20	95.30	95.30	95.30	95.20	95.10	95.00	94.80	94.60	94.30	94.10	93.80	93.40	93.10	92.70	92.30
80.0	92.50	93.30	93.80	94.10	94.40	94.50	94.60	94.60	94.60	94.50	94.40	94.30	94.10	93.90	93.70	93.50	93.20	92.90	92.60	92.30
85.0	91.90	92.60	93.00	93.30	93.50	93.70	93.80	93.80	93.80	93.80	93.80	93.70	93.60	93.50	93.30	93.20	93.00	92.70	92.50	92.30
90.0	91.60	92.00	92.30	92.50	92.70	92.90	93.00	93.00	93.10	93.10	93.10	93.10	93.00	93.00	92.90	92.80	92.70	92.60	92.40	92.30
95.0	91.60	91.80	91.90	92.00	92.10	92.20	92.30	92.30	92.40	92.40	92.40	92.40	92.40	92.40	92.40	92.40	92.40	92.30	92.30	92.30
98.0	92.00	92.00	92.10	92.10	92.10	92.10	92.20	92.20	92.20	92.20	92.20	92.20	92.20	92.30	92.30	92.30	92.30	92.30	92.30	92.30

Mean Annual Mass Removal Efficiencies for 3.00-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.30	99.50	99.60	99.60	99.50	99.40	99.20	99.00	98.80	98.50	98.10	97.70	97.30	96.90	96.40	95.90	95.30	94.70	94.10	93.50
35.0	98.90	99.20	99.40	99.40	99.30	99.20	99.10	98.90	98.60	98.30	98.00	97.60	97.20	96.80	96.30	95.80	95.30	94.70	94.10	93.50
40.0	98.40	98.90	99.10	99.10	99.10	99.00	98.90	98.70	98.50	98.20	97.90	97.50	97.10	96.70	96.20	95.70	95.20	94.70	94.10	93.50
45.0	97.90	98.50	98.80	98.80	98.80	98.70	98.60	98.50	98.30	98.00	97.70	97.30	97.00	96.60	96.10	95.60	95.10	94.60	94.10	93.50
50.0	97.40	98.10	98.40	98.50	98.50	98.40	98.30	98.20	98.00	97.70	97.50	97.10	96.80	96.40	96.00	95.50	95.10	94.60	94.00	93.50
55.0	96.70	97.60	97.90	98.10	98.10	98.10	98.00	97.90	97.70	97.40	97.20	96.90	96.60	96.20	95.90	95.40	95.00	94.50	94.00	93.50
60.0	96.20	97.10	97.50	97.60	97.70	97.70	97.60	97.50	97.30	97.10	96.90	96.60	96.40	96.00	95.70	95.30	94.90	94.50	94.00	93.50
65.0	95.50	96.40	96.90	97.10	97.20	97.20	97.10	97.00	96.90	96.70	96.60	96.30	96.10	95.80	95.50	95.10	94.80	94.40	93.90	93.50
70.0	94.90	95.70	96.20	96.40	96.60	96.60	96.60	96.50	96.50	96.30	96.20	96.00	95.80	95.50	95.20	94.90	94.60	94.30	93.90	93.50
75.0	94.20	95.00	95.40	95.70	95.90	96.00	96.00	96.00	95.90	95.90	95.70	95.60	95.40	95.20	95.00	94.70	94.50	94.20	93.80	93.50
80.0	93.50	94.20	94.70	95.00	95.20	95.30	95.40	95.40	95.40	95.30	95.30	95.10	95.00	94.90	94.70	94.50	94.30	94.00	93.80	93.50
85.0	93.10	93.60	94.00	94.30	94.50	94.60	94.70	94.70	94.80	94.70	94.70	94.60	94.60	94.50	94.40	94.20	94.10	93.90	93.70	93.50
90.0	92.80	93.10	93.40	93.60	93.80	93.90	94.00	94.10	94.10	94.10	94.10	94.10	94.10	94.00	94.00	93.90	93.80	93.70	93.60	93.50
95.0	92.80	93.00	93.10	93.20	93.30	93.30	93.40	93.50	93.50	93.50	93.60	93.60	93.60	93.60	93.60	93.60	93.60	93.60	93.50	93.50
98.0	93.20	93.20	93.30	93.30	93.30	93.30	93.40	93.40	93.40	93.40	93.40	93.40	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50

Table A-3 Mean Annual Mass Removal Efficiencies for Zone 4

Mean Annual Mass Removal Efficiencies for 3.25-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.40	99.60	99.60	99.60	99.60	99.50	99.40	99.20	99.00	98.80	98.50	98.20	97.80	97.40	97.00	96.50	96.10	95.60	95.00	94.50
35.0	99.10	99.40	99.50	99.50	99.40	99.40	99.20	99.10	98.90	98.70	98.40	98.10	97.70	97.30	96.90	96.50	96.00	95.50	95.00	94.50
40.0	98.70	99.10	99.20	99.30	99.20	99.20	99.10	98.90	98.70	98.50	98.20	97.90	97.60	97.20	96.80	96.40	96.00	95.50	95.00	94.50
45.0	98.20	98.80	98.90	99.00	99.00	98.90	98.80	98.70	98.50	98.30	98.10	97.80	97.50	97.10	96.80	96.30	95.90	95.50	95.00	94.50
50.0	97.70	98.40	98.60	98.70	98.70	98.70	98.60	98.50	98.30	98.10	97.90	97.60	97.30	97.00	96.60	96.30	95.90	95.40	95.00	94.50
55.0	97.20	98.00	98.20	98.40	98.40	98.40	98.30	98.20	98.10	97.90	97.60	97.40	97.10	96.80	96.50	96.20	95.80	95.40	94.90	94.50
60.0	96.70	97.50	97.80	98.00	98.00	98.00	98.00	97.90	97.70	97.60	97.40	97.20	96.90	96.70	96.40	96.00	95.70	95.30	94.90	94.50
65.0	96.20	96.90	97.30	97.50	97.60	97.60	97.60	97.50	97.40	97.20	97.10	96.90	96.70	96.40	96.20	95.90	95.60	95.20	94.90	94.50
70.0	95.60	96.40	96.80	97.00	97.10	97.10	97.10	97.10	97.00	96.90	96.70	96.60	96.40	96.20	96.00	95.70	95.40	95.10	94.80	94.50
75.0	95.00	95.70	96.10	96.40	96.50	96.60	96.60	96.60	96.50	96.50	96.40	96.20	96.10	95.90	95.70	95.50	95.30	95.00	94.80	94.50
80.0	94.50	95.10	95.50	95.70	95.90	96.00	96.00	96.10	96.00	96.00	95.90	95.90	95.80	95.60	95.50	95.30	95.10	94.90	94.70	94.50
85.0	94.00	94.50	94.80	95.10	95.20	95.40	95.40	95.50	95.50	95.50	95.50	95.40	95.40	95.30	95.20	95.10	94.90	94.80	94.70	94.50
90.0	93.80	94.10	94.30	94.50	94.60	94.80	94.80	94.90	94.90	95.00	95.00	95.00	94.90	94.90	94.90	94.80	94.70	94.70	94.60	94.50
95.0	93.80	94.00	94.10	94.20	94.20	94.30	94.40	94.40	94.40	94.50	94.50	94.50	94.50	94.50	94.50	94.50	94.50	94.50	94.50	94.50
98.0	94.20	94.20	94.20	94.30	94.30	94.30	94.30	94.40	94.40	94.40	94.40	94.40	94.40	94.50	94.50	94.50	94.50	94.50	94.50	94.50

Mean Annual Mass Removal Efficiencies for 3.50-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.50	99.70	99.70	99.70	99.70	99.60	99.50	99.40	99.20	99.00	98.80	98.50	98.20	97.80	97.50	97.10	96.70	96.20	95.80	95.30
35.0	99.20	99.50	99.50	99.60	99.50	99.50	99.40	99.20	99.10	98.90	98.70	98.40	98.10	97.80	97.40	97.00	96.60	96.20	95.80	95.30
40.0	98.90	99.20	99.40	99.40	99.40	99.30	99.20	99.10	98.90	98.80	98.50	98.30	98.00	97.70	97.30	97.00	96.60	96.20	95.70	95.30
45.0	98.50	98.90	99.10	99.20	99.20	99.10	99.00	98.90	98.80	98.60	98.40	98.20	97.90	97.60	97.30	96.90	96.50	96.20	95.70	95.30
50.0	98.00	98.60	98.80	98.90	98.90	98.90	98.80	98.70	98.60	98.40	98.20	98.00	97.70	97.50	97.20	96.80	96.50	96.10	95.70	95.30
55.0	97.60	98.30	98.50	98.60	98.60	98.60	98.60	98.50	98.40	98.20	98.00	97.80	97.60	97.30	97.00	96.70	96.40	96.10	95.70	95.30
60.0	97.20	97.80	98.10	98.30	98.30	98.30	98.30	98.20	98.10	98.00	97.80	97.60	97.40	97.20	96.90	96.60	96.30	96.00	95.70	95.30
65.0	96.70	97.40	97.70	97.90	97.90	98.00	97.90	97.90	97.80	97.70	97.50	97.40	97.20	97.00	96.70	96.50	96.20	95.90	95.60	95.30
70.0	96.20	96.90	97.20	97.40	97.50	97.60	97.50	97.50	97.40	97.30	97.20	97.10	96.90	96.80	96.60	96.30	96.10	95.90	95.60	95.30
75.0	95.70	96.30	96.70	96.90	97.00	97.10	97.10	97.10	97.00	97.00	96.90	96.80	96.70	96.50	96.40	96.20	96.00	95.80	95.50	95.30
80.0	95.30	95.80	96.10	96.30	96.50	96.50	96.60	96.60	96.60	96.60	96.50	96.40	96.40	96.30	96.10	96.00	95.80	95.70	95.50	95.30
85.0	94.80	95.20	95.50	95.70	95.90	96.00	96.10	96.10	96.10	96.10	96.10	96.10	96.00	96.00	95.90	95.80	95.70	95.60	95.40	95.30
90.0	94.60	94.90	95.10	95.20	95.40	95.50	95.50	95.60	95.60	95.70	95.70	95.70	95.70	95.60	95.60	95.60	95.50	95.40	95.40	95.30
95.0	94.70	94.80	94.90	95.00	95.00	95.10	95.20	95.20	95.20	95.30	95.30	95.30	95.30	95.30	95.30	95.30	95.30	95.30	95.30	95.30
98.0	95.00	95.00	95.10	95.10	95.10	95.10	95.20	95.20	95.20	95.20	95.20	95.20	95.20	95.30	95.30	95.30	95.30	95.30	95.30	95.30

Mean Annual Mass Removal Efficiencies for 3.75-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.70	99.70	99.70	99.70	99.70	99.70	99.60	99.50	99.30	99.20	99.00	98.70	98.50	98.20	97.90	97.50	97.20	96.80	96.40	96.00
35.0	99.30	99.50	99.60	99.60	99.60	99.60	99.50	99.40	99.20	99.10	98.90	98.70	98.40	98.10	97.80	97.50	97.10	96.80	96.40	96.00
40.0	99.00	99.30	99.40	99.50	99.50	99.40	99.30	99.20	99.10	99.00	98.80	98.60	98.30	98.10	97.80	97.40	97.10	96.70	96.40	96.00
45.0	98.70	99.10	99.20	99.30	99.30	99.30	99.20	99.10	99.00	98.80	98.70	98.40	98.20	98.00	97.70	97.40	97.10	96.70	96.40	96.00
50.0	98.30	98.80	99.00	99.10	99.10	99.00	99.00	98.90	98.80	98.70	98.50	98.30	98.10	97.80	97.60	97.30	97.00	96.70	96.30	96.00
55.0	98.00	98.50	98.70	98.80	98.80	98.80	98.80	98.70	98.60	98.50	98.30	98.10	97.90	97.70	97.50	97.20	96.90	96.60	96.30	96.00
60.0	97.60	98.10	98.40	98.50	98.50	98.50	98.50	98.50	98.40	98.30	98.10	98.00	97.80	97.60	97.40	97.10	96.90	96.60	96.30	96.00
65.0	97.10	97.70	98.00	98.20	98.20	98.20	98.20	98.20	98.10	98.00	97.90	97.70	97.60	97.40	97.20	97.00	96.80	96.50	96.30	96.00
70.0	96.70	97.30	97.60	97.80	97.90	97.90	97.90	97.90	97.80	97.70	97.60	97.50	97.40	97.20	97.10	96.90	96.70	96.50	96.20	96.00
75.0	96.30	96.80	97.10	97.30	97.40	97.50	97.50	97.50	97.50	97.40	97.30	97.20	97.10	97.00	96.90	96.70	96.60	96.40	96.20	96.00
80.0	95.90	96.40	96.60	96.80	97.00	97.00	97.10	97.10	97.10	97.00	97.00	96.90	96.90	96.80	96.70	96.60	96.40	96.30	96.10	96.00
85.0	95.60	95.90	96.10	96.30	96.40	96.50	96.60	96.60	96.70	96.70	96.60	96.60	96.60	96.50	96.50	96.40	96.30	96.20	96.10	96.00
90.0	95.30	95.60	95.70	95.90	96.00	96.10	96.10	96.20	96.20	96.30	96.30	96.30	96.30	96.20	96.20	96.20	96.10	96.10	96.00	96.00
95.0	95.40	95.50	95.60	95.60	95.70	95.80	95.80	95.80	95.90	95.90	95.90	96.00	96.00	96.00	96.00	96.00	96.00	96.00	96.00	96.00
98.0	95.70	95.70	95.70	95.80	95.80	95.80	95.80	95.80	95.90	95.90	95.90	95.90	95.90	95.90	95.90	95.90	95.90	96.00	96.00	96.00

Mean Annual Mass Removal Efficiencies for 4.00-inches of Retention for Zone 4

NDCIA CN	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	99.70	99.80	99.80	99.80	99.80	99.80	99.70	99.60	99.50	99.30	99.10	99.00	98.70	98.50	98.20	97.90	97.60	97.30	96.90	96.50
35.0	99.50	99.60	99.70	99.70	99.70	99.70	99.60	99.50	99.40	99.20	99.10	98.90	98.70	98.40	98.20	97.90	97.60	97.20	96.90	96.50
40.0	99.20	99.40	99.50	99.60	99.60	99.50	99.50	99.40	99.30	99.10	99.00	98.80	98.60	98.40	98.10	97.80	97.50	97.20	96.90	96.50
45.0	98.90	99.20	99.40	99.40	99.40	99.40	99.30	99.20	99.10	99.00	98.90	98.70	98.50	98.30	98.00	97.80	97.50	97.20	96.90	96.50
50.0	98.60	99.00	99.10	99.20	99.20	99.20	99.10	99.10	99.00	98.90	98.70	98.60	98.40	98.20	97.90	97.70	97.40	97.10	96.80	96.50
55.0	98.20	98.70	98.90	99.00	99.00	99.00	98.90	98.90	98.80	98.70	98.60	98.40	98.20	98.10	97.80	97.60	97.40	97.10	96.80	96.50
60.0	97.90	98.40	98.60	98.70	98.80	98.80	98.70	98.70	98.60	98.50	98.40	98.30	98.10	97.90	97.70	97.50	97.30	97.10	96.80	96.50
65.0	97.60	98.00	98.30	98.40	98.50	98.50	98.50	98.40	98.40	98.30	98.20	98.10	97.90	97.80	97.60	97.40	97.20	97.00	96.80	96.50
70.0	97.10	97.60	97.90	98.10	98.10	98.20	98.20	98.20	98.10	98.10	98.00	97.90	97.70	97.60	97.50	97.30	97.10	96.90	96.70	96.50
75.0	96.80	97.20	97.50	97.70	97.80	97.80	97.90	97.80	97.80	97.80	97.70	97.60	97.50	97.40	97.30	97.20	97.00	96.90	96.70	96.50
80.0	96.40	96.80	97.10	97.30	97.40	97.50	97.50	97.50	97.50	97.40	97.40	97.30	97.30	97.20	97.10	97.00	96.90	96.80	96.70	96.50
85.0	96.20	96.50	96.70	96.80	96.90	97.00	97.00	97.10	97.10	97.10	97.10	97.10	97.00	97.00	96.90	96.90	96.80	96.70	96.60	96.50
90.0	95.90	96.10	96.30	96.40	96.50	96.60	96.60	96.70	96.70	96.70	96.80	96.80	96.80	96.70	96.70	96.70	96.70	96.60	96.60	96.50
95.0	96.00	96.10	96.10	96.20	96.30	96.30	96.40	96.40	96.40	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50
98.0	96.30	96.30	96.30	96.30	96.40	96.40	96.40	96.40	96.40	96.40	96.40	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50	96.50

Table A-3 Mean Annual Mass Removal Efficiencies for Zone 4

Land Use	Event Mean Concentration (mg/l)	
	Total N	Total P
Low-Density Residential	1.610	0.191
Single-Family	2.070	0.327
Multi-Family	2.320	0.520
Low-Density Commercial	1.180	0.179
High-Density Commercial	2.400	0.345
Light Industrial	1.200	0.260
Highway	1.640	0.220
Agricultural, Pasture	3.470	0.616
Agricultural, Citrus	2.240	0.183
Agricultural, Row Crops	2.650	0.593
Agricultural, General	2.790	0.431
Undeveloped	1.150	0.055
Undeveloped, Dry Prairie	1.950	0.107
Undeveloped, Hydric Hammock	1.072	0.026
Undeveloped, Marl Prairie	0.603	0.010
Undeveloped, Mesic Flatwoods	1.000	0.034
Undeveloped, Mixed Hardwood Forest	0.288	0.501
Undeveloped, Ruderal/Upland Pine	1.318	0.347
Undeveloped, Scrubby Flatwoods	1.023	0.027
Undeveloped, Upland Hardwood	0.891	0.269
Undeveloped, Upland Mixed Forest	0.676	2.291
Undeveloped, Wet Flatwoods	1.175	0.015
Undeveloped, Wet Prairie	0.776	0.009
Undeveloped, Xeric Hammock	1.318	2.816
Undeveloped, Xeric Scrub	1.158	0.096
Mining / Extractive	1.180	0.150

Table A-4 – Event Mean Concentrations / Runoff Characteristics

(Source "Draft Best Management Practice Analysis Aid" from *University of Central Florida, Stormwater Management Academy*)