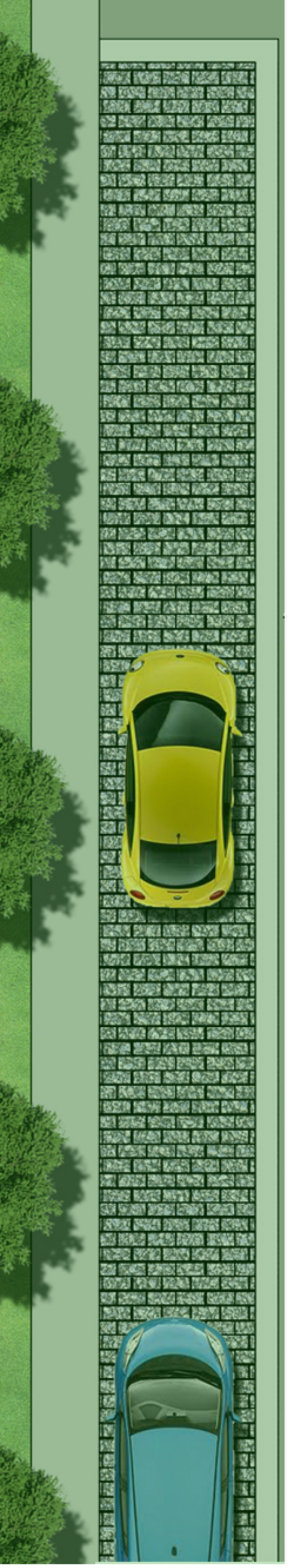
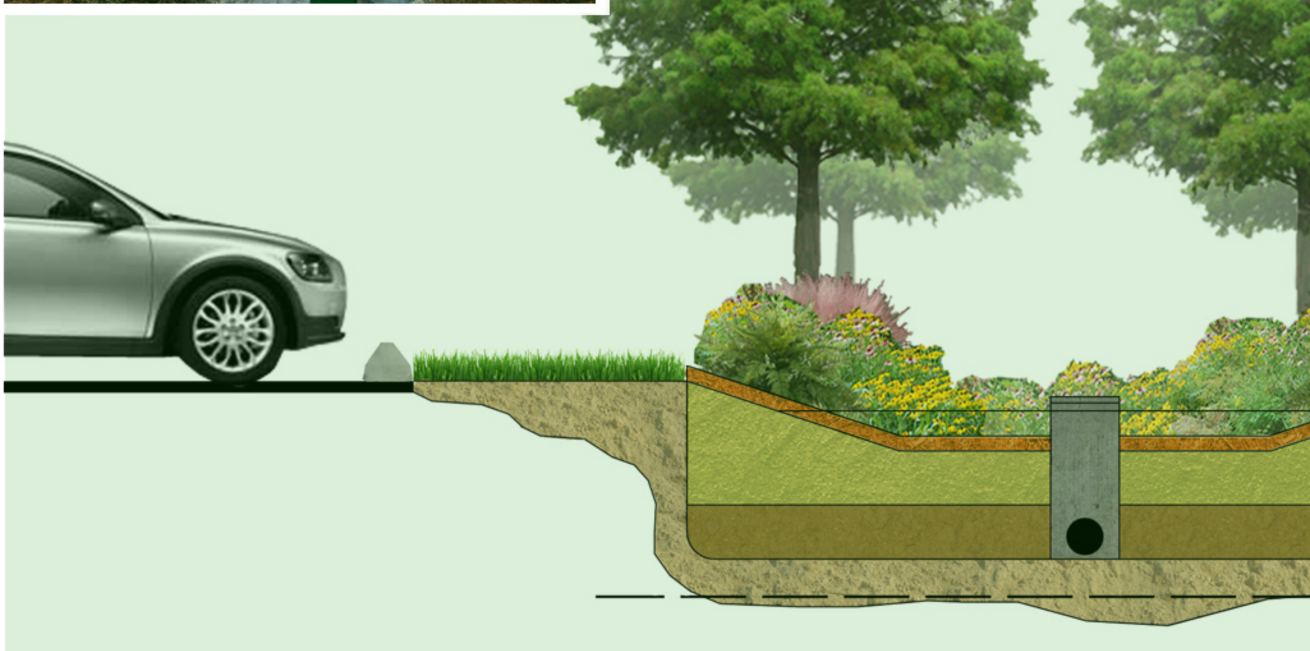
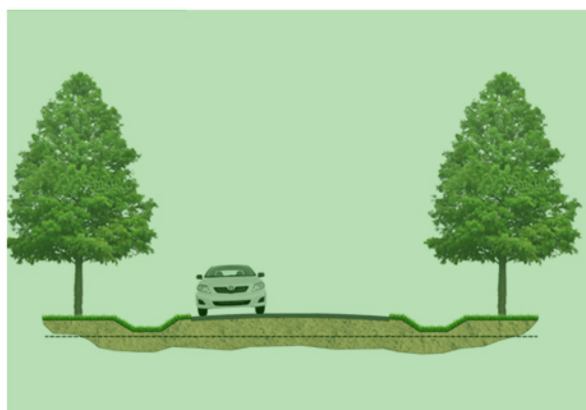
DUVAL COUNTY LOW-IMPACT DEVELOPMENT DESIGN MANUAL





Jacksonville
Where Florida Begins.



DUVAL COUNTY

LOW-IMPACT DEVELOPMENT

MANUAL

Prepared for:

CITY OF JACKSONVILLE

Ed Ball Building

214 North Hogan Street, Suite 600

Jacksonville, Florida 32202

Prepared by:

JONES EDMUNDS & ASSOCIATES, INC.

730 NE Waldo Road

Gainesville, Florida 32641

July 2013

IF A HARDCOPY OF THIS

DOCUMENT IS NEEDED,

PLEASE TRY TO SAVE PAPER

AND PRINT THIS DOCUMENT

DOUBLE-SIDED.

This manual is available for download from the following website:

http://www.coj.net/departments/planning-and-development/community-planning-division/plans-and-studies/lid-manual.aspx

ACKNOWLEDGEMENT

Significant portions of the Duval County LID Manual are based on the following:

- Preliminary Sarasota County LID Manual (March 2012 – Working Copy)
- Florida Department of Environmental Protection and Water Management Districts Environmental Resource Permit Stormwater Quality Applicant's Handbook (March 2010 – Draft).
- St. Johns River Water Management District – Applicants Handbook (December 2010)

DISCLAIMER

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 and should be used only with careful consideration of applicable laws, rules, codes, ordinances, standards, and the like, including without limitation the Americans with Disabilities Act 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 planning, designing, constructing, operating, and maintaining building and development projects in Duval County, Florida.

The authors have made a good-faith effort to provide timely and correct information. However, some inaccuracies may occur due to, for example, a change in applicable laws since publication. For this reason, the authors cannot and do not represent or warrant the completeness or accuracy of the information. The information is supplied on the condition that the reader will make his or her determination as to its suitability for his or her purposes. The responsibility for using a standard in this manual remains with the professional or other person responsible for planning, designing, constructing, operating, and maintaining a specific project.

The use of brand names in this publication does not indicate an endorsement by the authors, the City of Jacksonville, or the State of Florida.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

FOREWORD

The St. Johns River is Duval County's greatest natural resource. The river plays an important part in the region's history as well as its economic and recreational livelihood. However, the river has suffered from excessive nutrient loading from wastewater and stormwater discharges and has been deemed impaired by the Florida Department of Environmental Protection. A Lower St. Johns River Nutrient Basin Management Actin Plan (BMAP) issued by FDEP Secretarial Order in October 2008 requires specific nutrient-loading reductions for all entities discharging to the river.

The *Duval County Low-Impact Development Manual* is intended to be used as a stormwater management tool for municipalities to meet BMAP obligations and for developers to have alternatives that meet local design specifications that also comply with Environmental Resource Permit requirements. The manual is based on the *Preliminary Sarasota County Low-Impact Development Manual* and its strategies. Although State and local environmental regulations of Duval and Sarasota Counties are similar, climate, soils, and plant hardiness zones differ. Therefore, different parameters are required in Low-Impact Development design practices.

1 MANUAL OVERVIEW

1.1 PURPOSE OF MANUAL

This manual provides technical guidance and design specifications on Low-Impact Development (LID) stormwater management practices to apply to projects in Duval County, Florida. This manual is not to be used in place of but rather as a supplement to the stormwater and surface water management guidance documents of the City of Jacksonville, St. Johns River Water Management District (SJRWMD), and other municipalities within Duval County with regard to local design criteria and LID applicability. The guidance provided in the manual is designed to be flexible, with performance criteria provided where possible. The first version of this manual is limited to detailed design information for three practices that were selected as being the most applicable for right-of-way in Duval County but may also be used in other stormwater management scenarios. Additional practices will be added to the manual as the need arises. Depending on the magnitude of specific or cumulative impacts, other methods of meeting the overall water resources objectives of the City of Jacksonville and SJRWMD may 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 Duval County. However, Duval County encourages the use of LID practices where possible to help meet its water resource objectives. This manual is expected to be adopted by the City of Jacksonville Subdivision Standards and Policy Advisory Committee (SSPAC) and to be incorporated by reference as an attachment to the City of Jacksonville's Land Development Procedures Manual.

1.2 BACKGROUND

LID is a stormwater management strategy that uses a suite of structural and non-structural hydrologic controls 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 that typically control and treat runoff using a single engineered stormwater pond at the "bottom of the hill" or the lowest point of an area, 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, designs, and practices is to improve the overall effectiveness and efficiency of stormwater management relative to conventional systems and thus 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 Duval County. Regardless of the project context, LID requires the following core site-planning and design objectives to be considered:

1. Preserve or conserve existing site features and assets that facilitate natural hydrologic function.
2. Minimize runoff generated 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 soil compaction 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 a 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 Duval County and SJRWMD 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 Duval 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.

1.3 Design Goal

The applicant must provide reasonable assurance that the use of LID will not:

- Cause adverse water quantity impacts to receiving waters.
- Cause flooding to on-site or off-site property.
- Cause adverse impacts to existing surface water storage and conveyance capabilities.
- Adversely impact the maintenance of surface water or groundwater levels or surface water flows.

New development should be designed to comply with the stormwater quality and quantity requirements outlined in:

- The City of Jacksonville Land Development Procedures Manual.
- The City of Jacksonville 2030 Comprehensive Plan—Infrastructure Element, Drainage Sub-Elements A and B.
- The City of Jacksonville Master Stormwater Plan.

Stormwater treatment systems should be designed to combine best management practices (BMPs) – structural and non-structural – in a series to achieve the water quality and quantity goals. Refer to Chapter 3 for permitting guidance and example design calculations that meet Environmental Resource Permit (ERP) and City of Jacksonville criteria. Design criteria in the SJRWMD ERP Applicants Handbook Volume II are intended to be flexible; however, other BMPs may be permitted under "non-presumptive" criteria. Applicants proposing "non-presumptive" stormwater treatment BMPs, including alternative LID practices, must provide reasonable assurance that State water quality standards will be met based on information specific to the proposed design. Reasonable assurance under "non-presumptive" criteria involves demonstrating an annual pollutant-load reduction of 80% with 95% for direct discharges to an Outstanding Florida Water (OFW).

1.4 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 Duval 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.

1.5 ORGANIZATION OF MANUAL

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

1.5.1 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 City of Jacksonville land development and stormwater management rules and requirements, Chapter 2 directs users of this manual to these guidance documents by reference.

1.5.2 CHAPTER 3: LID PRACTICES FOR DUVAL COUNTY

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

- Grassed Conveyance Swales (Section 3.1).
- Shallow Bioretention (Section 3.2).
- Pervious Pavements (Section 3.3).

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 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 appropriately planning, designing, constructing, installing, operating, and maintaining the LID practice or system.

Criteria in Chapter 3 are considered **minimum** standards for designing LID treatment systems in Duval County. Additional items are provided in case the applicant wants to enhance the water quality efficiency of the LID technique. Any single LID practice is unlikely to meet SJRWMD and City of Jacksonville water resource objectives; these practices are intended to 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. Users of this manual must consult with SJRWMD ERP criteria and the City of Jacksonville's guidance documents on land development and stormwater management, including the City Comprehensive Plan, Land Development Regulations, and Zoning Code for any variations from these criteria or additional standards that must be followed.

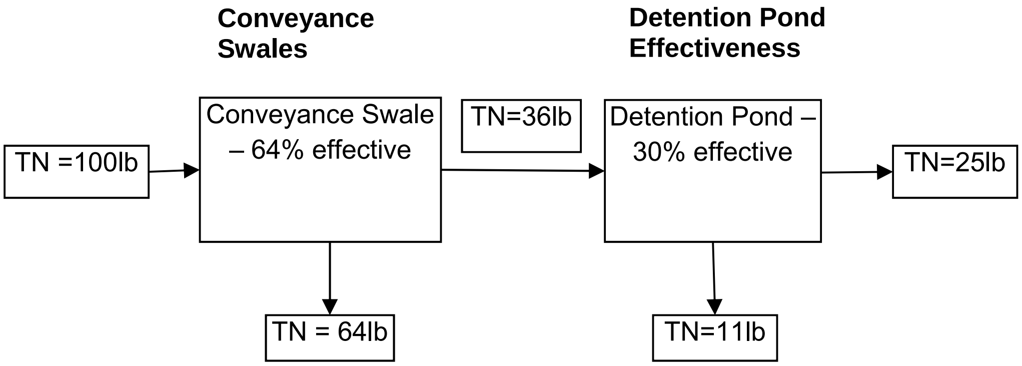
1.6 Demonstrating LID Effectiveness

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

1.6.1 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. Chapter 3 provides details such as design curves that can be used to calculate the average annual load reduction of some LID practices in Duval County. 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. Figure 1-1 shows an example of how this effectiveness can be demonstrated for Total Nitrogen (TN). The same approach can be used for other constituents.

Figure 1-1 Treatment Train Effectiveness for a Dry Treatment System Followed by a Wet Treatment System



See Section 3.1.3.2 for an example of how this would be calculated for a grassed conveyance swale.

1.6.2 Water Quantity

Most LID practices will provide some attenuation of peak flows and/or reduction in runoff volume during flood events. The effectiveness of some LID practice in reducing peak runoff rate and/or runoff volume can be demonstrated by modifying the Natural Resource Conservation Service (NRCS) Curve Number (CN) used to represent the LID practice and/or the area contributing to the practice. Chapter 3 provides details on how the CN should be modified. In some instances, the hydraulic functioning of the LID practice may be explicitly modeled.

1.7 Local Context

1.7.1 Duval County's Hydrology

LID applications should be designed to mimic the natural hydrologic functioning of a site. Five hydrologic soil groups, as classified by NRCS, are found in Duval County: 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). Figure 1-2 maps these hydrologic soil groups in Duval County. Most soils in Duval County are classified in the B/D hydrologic soil group due to a shallow seasonal high water level (SHWL), so the 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, with most development having occurred near the St. Johns River. Pine flatwoods dominate the west half of Duval County, while saltmarsh dominates the north portion. Figure 1-3 maps land use according to the SJRWMD 2009 land use, and Figure 1-4 maps the 9 major drainage basins in Duval County.

1.7.2 Urbanization and Water Quality Standards

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

While these stormwater rules and design criteria have been effective in addressing flood control and have facilitated an efficient process for managing stormwater runoff, 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 (e.g., potable water, shellfish propagation, recreation); nutrients in stormwater runoff – particularly nitrogen and phosphorus – have been identified as the cause of impairment in a majority of these water bodies (Florida Department of Environmental Protection, 2006b).

1.7.3 Standards Supporting LID

Although they may not use the term "Low-Impact Development" explicitly, many City of Jacksonville's ordinances, resolutions, and policies and SJRWMD's rules support the application of LID principles and design. City of Jacksonville documents that should be referenced with this manual to provide guidance on LID projects and to ensure compliance with requirements include but are not limited to the following:

- The City of Jacksonville 2030 Comprehensive Plan
  - Transportation Element
  - Recreation and Open Space Element
  - Conservation Coastal Management Element
  - Future Land Use Element
  - Infrastructure Element
  - Intergovernmental Coordination Element
- City of Jacksonville's Ordinance Code
  - Environmental Affairs Code (Title X)
  - Public Works and Utilities (Title XXI)

Figure 1-2 Hydrologic Soil Groups

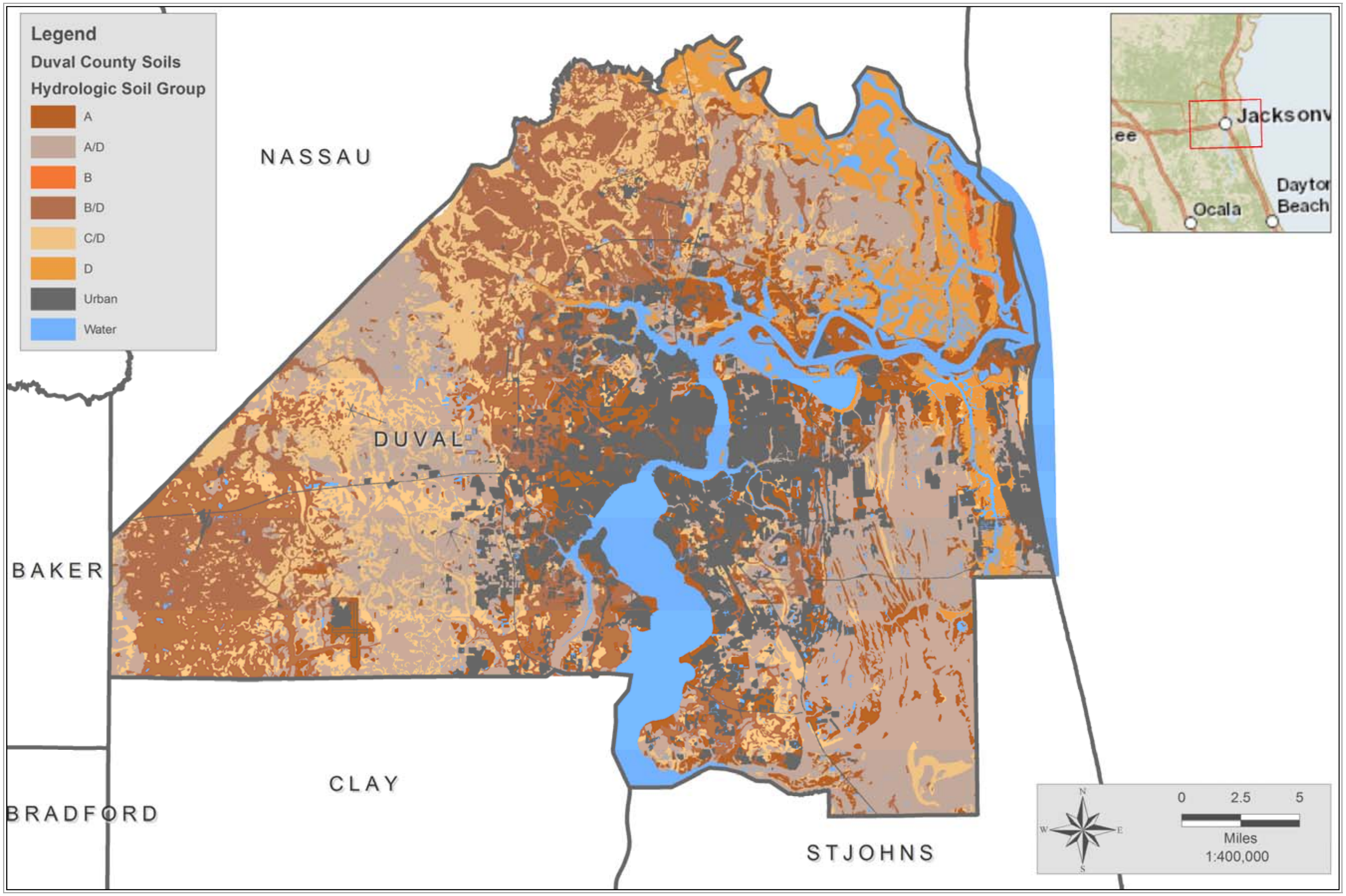


Figure 1-3 2009 Land Use

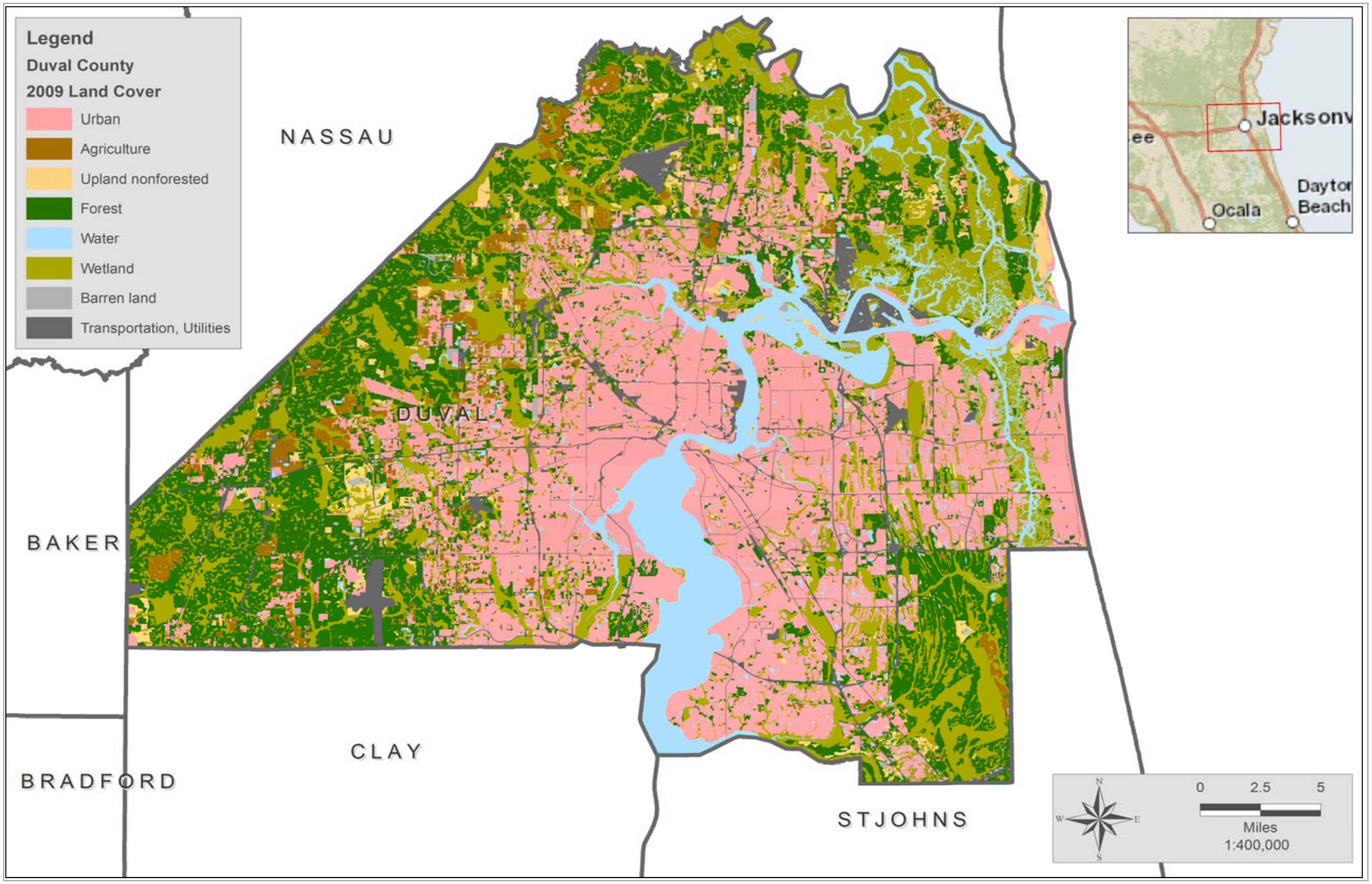
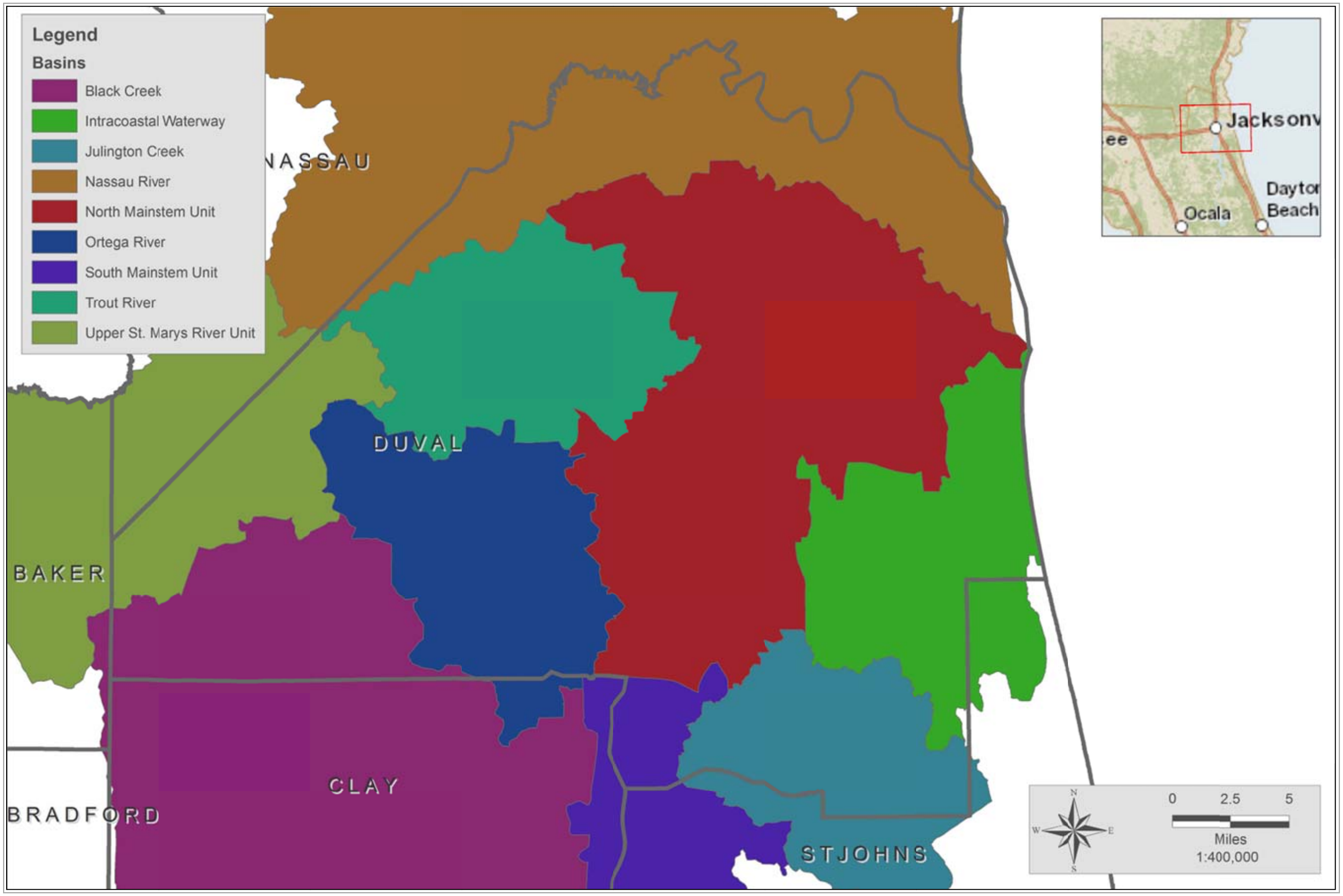


Figure 1-4 Major Drainage Basins



- City of Jacksonville Land Development Procedures Manual
- City of Jacksonville Zoning Regulations (Title XVII Section 656, City of Jacksonville Ordinance Code)

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.

1.8 TERMINOLOGY

This section defines terminology used throughout this manual.

- *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 B-1 in Appendix B).
- *Bioretention:* The use of shallow landscaped depressions with soils, mulch, and planted vegetation intended to prevent the discharge of a given volume of stormwater runoff into surface waters by providing complete on-site storage.
- *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 City of Jacksonville's 2030 Comprehensive Plan: Future Land Use Element.
- *Detention:* The collection and temporary storage of stormwater with subsequent gradual release of the stormwater.
- *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:* Any proposed material change in the use or character of the land, including but not limited to land-clearing associated with new construction, the placement of any structure or site improvement on the land, or expansion of existing buildings (Jacksonville, Florida, Ordinance Code, Zoning Section, Chapter 656-Zoning Code, Part 12—Landscape and Tree Protection Regulations).
- *Diameter at Breast Height (DBH):* The diameter of a plant's trunk or main stem 4.5 feet above the ground.
- *Directly Connected Impervious Area (DCIA):* The area covered by a building, impermeable pavement, and/or other impervious surfaces that drains directly into the conveyance without first flowing across sufficient permeable vegetated land area to allow for runoff infiltration.
- *Equivalent Impervious Area (EIA):* The area of a completely impervious watershed that would produce the same volume of runoff as the actual watershed.

- *Floodplain:* Land area subject to inundation by flood waters from a river, watercourse, or lake. Floodplains are delineated according to their estimated frequency of flooding.

- *Low-Impact Development*: A stormwater management approach that uses a suite of structural and non-structural hydrologic controls 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).

- *Nutrient-Sorption Layer:* A layer included in pervious pavement systems that absorbs nutrients, thereby reducing the nutrient loading from the system.

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

- *Predevelopment:* The natural vegetative community type of the project area.

- *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.

- *Protected Tree*: includes all of the following:

  - *Private protected tree* means any tree with a DBH of 6 inches or more located on any lot within 20 feet of a street right-of-way (including an approved private street or other access easement) or a tree with a DBH of 8 inches or more located within 10 feet of any other property line, or a tree with a DBH of 11.5 inches or more located elsewhere on the lot.

  - *Public protected tree* means any tree located on lands owned by the City of Jacksonville or other governmental agencies or authorities, or any land upon which easements are imposed for the benefit of the City of Jacksonville or other governmental agencies or authorities, or upon which other ownership control may be exerted by the City of Jacksonville or other governmental agencies or authorities, including rights-of-way, parks, public areas, and easements for drainage, sewer, water, and other public utilities, with:

    - A DBH of 6 inches or more located within a County, City, or other governmental right-of-way, or

    - A DBH of 6 inches or more and located on any lot within 20 feet of a street right-of-way, or

    - A DBH of 8 inches or more located on any lot within 10 feet of any other property line, or

    - A DBH of 11.5 inches or more located elsewhere on the lot.

- *Exceptional specimen tree* means any hardwood tree with a DBH of 24 inches or greater.

  (City of Jacksonville, Florida, Ordinance Code, Zoning Section, Chapter 656-Zoning Code, Part 12—Landscape and Tree Protection Regulations)

- *Rain Barrel:* A rainwater storage vessel with a capacity less than or equal to 80 gallons that captures runoff from a roof. Systems using rain barrels for storage, including systems that link several barrels together in series, do not constitute an acceptable BMP for the ERP program administered by SJRWMD.

- *Rainwater:* Runoff from a roof that is collected before it contacts the ground.

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

- *Redevelopment:* The construction of a stormwater treatment system on sites having existing commercial, industrial, institutional, or multi-family land uses where the existing impervious surface will be removed as part of the proposed activity.

- *Retention:* A system designed to prevent the discharge of a given volume of stormwater runoff into surface waters in the state by providing complete on-site storage. Examples are systems such as excavated or natural depression storage areas, pervious pavement with subgrade, or above-ground storage areas.

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

- *Site Plan:* 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 City regulations; proposed signs and lighting; and any other information that may be necessary or reasonably required.

- *Soils:* As defined in the current United States Department of Agriculture Soil Survey of Duval County.

- *Stormwater Harvesting:* Capturing stormwater for irrigation or other beneficial use.

- *Stormwater Management System:* A system that is designed and constructed or implemented to control discharges that are necessitated by rainfall events, incorporating methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water to prevent or reduce flooding, over drainage, environmental degradation, and water pollution or otherwise affect the quantity and quality of discharges from the system. [Sections 373.403(10) and 403.031(16), FS]

- *Survey:* A survey as defined in the Minimum Technical Standards for Surveying, Rule 5J-17, FAC.

- *Total Maximum Daily Load (TMDL):* The sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background for an impaired waterbody or waterbody segment. Prior to determining individual wasteload allocations and load allocations, the maximum amount of a pollutant that a waterbody or water segment can assimilate from all sources without exceeding water quality standards must first be calculated. A TMDL shall include either an implicit or explicit margin of safety or a consideration of seasonal variations. (Chapter 62-302.200, F.A.C.)

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

- *Turf Grass:* Continuous plant coverage consisting of grass species suited to growth in Duval County (City of Jacksonville, Florida, Ordinance Code, Zoning Section, Chapter 656-Zoning Code, Part 12—Landscape and Tree Protection Regulations).

- *Water or Waters in the State:* Any and all water on or beneath the ground surface or in the atmosphere, including natural or artificial watercourses, lakes, ponds, or diffused surface water and water percolating, standing, or flowing beneath the ground surface, as well as all coastal waters within the jurisdiction of the state. [Section 373.019(20), FS]

- *Water Quality Standards:* Standards set forth in Chapters 62-4, 62-302, 62-520, and 62-550, FAC, including the antidegradation provisions of Paragraphs 62-4.242(1)(a) and (b), FAC, Subsections 62-4.242(2) and (3), FAC, and Rule 62-302.300, FAC, and any special standards for Outstanding Florida Waters and Outstanding National Resource Waters set forth in Subsections 62-4.242(2) and (3), FAC.

1.9 References

City of Jacksonville Land Development Procedures Manual (March 2012).

City of Jacksonville Ordinance Code (November 2012).

Florida Department of Environmental Protection. 2006a. *Water Resource Implementation Rule, Chapter 62-40, FAC*. May 7, 2006.

Florida Department of Environmental Protection. 2006b. *Integrated Water Quality Assessment for Florida: 2006 305(b) Report and 303(d) List Update.* May 2, 2006.

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.

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.

1.10 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, including rainfall tables for Duval County and a table of mean annual runoff coefficients

.

2 EVALUATING YOUR SITE AND PLANNING FOR LID

2.1 OVERVIEW

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 applying LID 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 the City of Jacksonville's development standards and stormwater management requirements.

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 City land-development standards are achieved.

Rather than focusing solely on treating stormwater runoff once it has been generated on 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 the 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 in which each individual practice provides incremental benefits that collectively achieve storage and pollution-control requirements. Design professionals 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:

- Preserve or conserve site features and assets that facilitate natural hydrologic function.
- Minimize runoff generated from impervious surfaces (i.e., use peak and total volume controls).
- Minimize runoff contamination (i.e., use load controls) as close to the source as possible.
- Promote distributed retention, detention, treatment, and infiltration of runoff.
- Capture and harvest stormwater on site.
- Minimize site disturbance and soil compaction through low-impact clearing, grading, and construction measures.
- Coordinate the construction schedule to minimize the area disturbed at any one time and plan construction phases to reduce the erosion potential of the site.

This chapter's overview of the site-assessment and planning processes 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 City of Jacksonville and SJRWMD staff at the pre-application meetings if they wish to include these as a part of their permitted stormwater treatment system.

2.2 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 developments typically require the following:

- Clearing on-site 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 carefully considering the project's intent and thoroughly evaluating, documenting, and analyzing predevelopment site conditions.

2.2.1 DEFINING PROJECT INTENT

The type of development being planned and the expected uses and 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 a project. The designer should consider the following questions regarding the project's fundamental intent:

- Is the project a new or greenfield development, redevelopment or infill, or retrofit of an existing site?
- Is the property planned (and zoned) for residential, commercial, industrial, or public use?
- What local standards and/or programs offer incentives for and/or discourage implementing certain LID practices?
- Who are the expected 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 locating stormwater ponds to allow stormwater to be efficiently captured and harvested. The number of potential practices for retrofit applications, on the other hand, might be limited 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 can also influence the appropriateness and effectiveness of LID systems. For example, stormwater systems in residential applications are typically exposed and can often be physically accessed by homeowners, so LID applications should not only function as stormwater quantity and quality measures but also should be perceived as functional community amenities rather than nuisances or hazards.

2.2.2 Evaluating Predevelopment Conditions

When evaluating a site for the feasibility of integrating LID practices, the design professional must conduct a thorough analysis of predevelopment conditions. For this manual, predevelopment conditions are site features – including 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, the design professional should identify, understand, and document site conditions that facilitate rainfall interception, capture, storage, evaporation, transpiration, infiltration, treatment, and harvesting; note site features that restrict these natural hydrologic processes; and 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 (e.g., tree canopy, vegetation) 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 site topography 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 Duval County, available at: http://websoilsurvey.nrcs.usda.gov/app/) and distributions on site and to what extent do they promote rainfall infiltration (i.e., what are their infiltration rates)? More than 60% of soils in Duval County are classified in the B/D, C/D, or A/D hydrologic soil group (not well-drained when wet) due to a shallow SHWL.
- 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 SHWL throughout the site?
- Do critical and sensitive areas (e.g., wetlands, riparian areas) that capture, uptake, and filter pollutants exist on site and have they been protected or disturbed?
- What physical structures (e.g., buildings, parking lots) 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 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.

Design professionals 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 datasets and analyses 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 Duval County (available at http://websoilsurvey.nrcs.usda.gov/app/) or other historical soil information.
- Tree and vegetation surveys.
- Rainfall data.
- Hydrologic analyses.
- Verifiable oral accounts of the natural hydrologic functioning of the site.
- Archaeological data.

With these, design professionals can identify key site opportunities for 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.

2.3 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, by extending 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 the entire suite of practices that might be applied in terms of their relationship to the seven fundamental LID principles discussed in this manual should be considered:

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 on-site SHWL.
7. Improve water quality.

2.3.1 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 protected tree survey.
- 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.

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

2.3.2 Minimizing and Controlling Runoff Generation at the Source

Conventional development practices modify natural site drainage pathways by introducing a network of impervious surfaces (e.g., rooftops, driveways, sidewalks, roads, gutters) that route stormwater away from the site or to stormwater treatment basins. While this process is very efficient at controlling runoff, it significantly alters the hydrologic signature of the site and increases runoff volumes and rates while conveying pollutants away from the site. Alternatively, LID emphasizes minimizing and controlling runoff and pollutant generation at the source. LID facilitates on-site 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. The following are 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):

- Preserving mature tree canopy, protected trees, and understory vegetation.
- Clustering homes, buildings, and other structures on smaller lots.

- Constructing greenroof stormwater treatment systems.
- Minimizing impervious areas.
- Minimizing directly connected impervious areas (DCIA).
- Using natural topographic lows and natural drainage paths as a part of the drainage system design.
- Using shared driveways in residential applications.
- Using narrower roads with a pervious shoulder and/or right-of-way.
- Using a road layout that minimizes linear impervious area.
- Using alternative parking lot designs that minimize 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 vegetation establishment only or using smart water-application technologies, such as soil-moisture sensors, that maximize irrigation efficiency.

2.3.3 Promoting Infiltration

Many LID strategies that reduce stormwater generation 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 SHWL and soil types, infiltration-dependent LID practices can be designed to perform effectively as part of a treatment train under most site conditions in Duval County. Design professionals should identify optimal areas for locating infiltration-dependent stormwater practices (i.e., those with the highest infiltration rates) 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.
- Using pervious pavements (Section 3.3) for parking lots and residential parking areas, driveways, walking and bike paths, sidewalks, and emergency vehicle access lanes.
- Using grassed conveyance swales to convey stormwater.
- Using vegetated swales with check dams to promote retention on a site.
- Engineering or amending soils to improve infiltration properties.
- Ecologically and biologically enhancing stormwater treatment ponds.

2.3.4 Promoting Stormwater Harvesting

Design professionals should consider stormwater an asset that can be used to reduce the impact of development projects on Duval County water resources. Rather than designing systems that allow stormwater to leave the site, often exacerbating downstream flooding and surface water degradation, LID promotes treating and harvesting stormwater on site. Stormwater harvesting can offset potable water demands significantly, particularly when used for outdoor irrigation, which accounts for approximately 50% of residential households' water use in Florida (Purdum, 2002). 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, and graywater for irrigating lawns and landscape beds, irrigating green roofs, washing vehicles, cooling tower make-up water, and toilet flushing as approved by Duval County health codes.
- Stormwater harvesting ponds, typically used for irrigating lawns and landscape beds.
- Distribution pipes for non-potable water (i.e., stormwater harvesting or reclaimed water).

2.3.5 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, exporting native soils, importing fill, mass grading, and using heavy machinery for construction in sensitive areas. Compacting soils reduces the pore space available for stormwater storage and infiltration. 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 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.
- Sequencing construction to minimize the disturbed area and reduce the potential for erosion on the site.

City of Jacksonville stormwater regulations provide maximum allowable compaction values when constructing certain LID practices, such as pervious pavements (see Section 3.3).

2.4 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 individual practices or 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; however, these requirements should be confirmed with the City and SJRWMD staff during the pre-application meetings. The performance requirements and recertification requirements for stormwater systems may differ between the City and SJRWMD.

2.5 PROJECT GUIDANCE FOR DESIGN PROFESSIONALS

LID techniques offer a wide diversity of applications for both new and redevelopment projects that can be implemented in virtually any project situation encountered within Duval County. In planning any LID project, design professionals should note that LID techniques complement traditional stormwater treatment BMPs. They do not necessarily provide the full water quality treatment or stormwater attenuation requirements of City of Jacksonville or SJRWMD. LID practices may often require a combination of treatment strategies to achieve the treatment goal. In this regard, the design professional is encouraged to consider various LID techniques in this manual to use in a treatment-train arrangement to optimize the effectiveness of LID and to achieve the traditional water quality benefits recognized through City of Jacksonville permitting and the SJRWMD ERP review process.

The traditional approach to stormwater management design is based on a “presumed treatment criteria” for stormwater that relies on demonstrating infiltration and storage of a specified volume of stormwater. The City of Jacksonville recognizes that LID practices offer additional treatment benefits through detention and natural treatment processes. These additional processes are environmentally beneficial and offer advantages for the design professional to meet new proposed treatment goals associated with TMDLs. The design professional may be required to provide supporting technical documentation to demonstrate reasonable assurance to meet State water quality criteria for LID practices to successfully secure a permit. To achieve a successfully permitted project, the design professional must understand how environmental variables will affect the feasibility and placement of treatment features.

To achieve a best-fit LID practice for each site, a qualitative LID Guidance Tool has been provided in Appendix A for design professionals that follow a “consumers’ guide” approach to understanding the benefits or challenges of each LID practice in this manual. With this tool, the stormwater professional can streamline the planning approach and focus on only those LID practices that are practical to apply at each site according to three major categories:

- General Site Considerations: What is the nature of the project?
- Environmental Site Considerations: What natural features may provide opportunities or influence LID performance?
- Special Watershed Site Considerations: Are there any special stormwater management or TMDL issues that may need to be addressed with LID practices?

2.6 REFERENCES

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).

3 LID PRACTICES IN DUVAL COUNTY

3.1 GRASSED CONVEYANCE SWALES

Key Considerations	**Practice Intent:** ▪ Retain, infiltrate, and treat stormwater from small events close to source. ▪ Convey stormwater from larger events to the next practice in the treatment train. **Design Criteria:** ▪ Top width-to-depth ratio equal to or greater than 6:1. ▪ Recommended bottom width of 2 to 8 feet. ▪ Longitudinal slope between 0.5% and 3%. ▪ Landscape with turf grass suitable for soil stabilization, maintainability, stormwater treatment and conveyance, and nutrient uptake. **Advantage/Benefits:** ▪ Good retrofit capability. ▪ Can be planned as an aesthetic feature. ▪ Low construction cost. ▪ Low maintenance cost. ▪ Combines treatment and conveyance. **Disadvantages/Limitations:** ▪ More frequent maintenance than a curb-and-gutter system. ▪ Cannot be used on steep slopes. **Maintenance Requirements:** ▪ Maintain grass heights of 4 to 6 inches. ▪ Remove trash, litter, and sediment. **Monitoring/Record Keeping:** ▪ None. **Recovery:** ▪ Standing water must be recovered within 72 hours.
Pollutant-Removal Potential	**H** **Total Suspended Solids.** **M** **Nutrients**—Total Phosphorus/Total Nitrogen. **L** **Metals**—Cadmium, Copper, Lead, and Zinc. **L** **Pathogens**—Coliform, Streptococci, and E.Coli.
Stormwater Management Suitability	☒ **Water Quality** ☐ **Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Well suited **High-Density/Urban:** Less frequent **Drainage Area:** To receive pollutant-load-reduction credits, point discharges to a swale should be from areas of 1 acre or less. This area threshold does not apply to inflows along the swale length. **Shallow Water Table:** To receive pollutant-load-reduction credits, the SHWL should be at least 6 inches below the bottom of the grassed conveyance swale. **Soils:** Water quality benefits are reduced by low soil permeability.
Other Considerations:	Use of drought-tolerant turf grass is recommended.

L—Low, **M**—Moderate, **H**—High

3.1.1 General

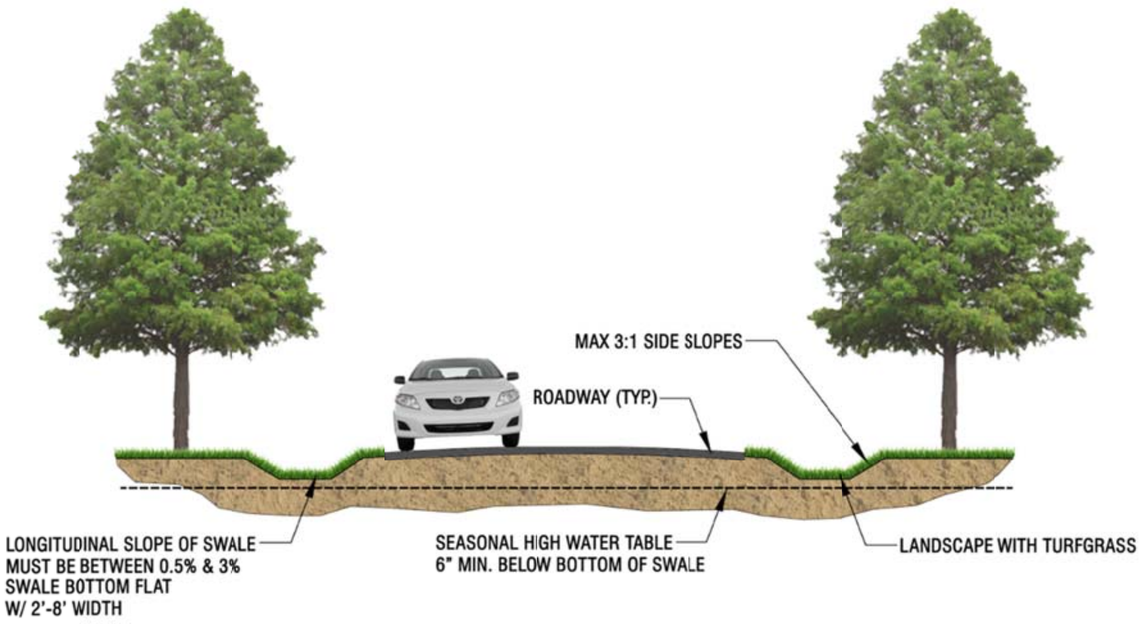
3.1.1.1 Overview and Intent

A *swale* is defined by the State of Florida as a manmade trench that meets the following criteria:

- Has a top width-to-depth ratio of the cross section equal to or greater than 6:1 (horizontal:vertical) or side slopes equal to or greater than 3 feet horizontal to 1 foot vertical.
- Contains contiguous areas of standing or flowing water only after rainfall.
- Is planted with or has stabilized vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake.
- Is designed to account for soil erodibility, soil percolation, slope, slope length, and drainage area to prevent erosion and reduce pollutant concentration of any discharge.

Grassed conveyance swales are used to move stormwater away from critical infrastructure, such as a road. However, these systems are also able to provide water quality improvement through processes such as infiltration, settling, and filtration. Grassed conveyance swales are included in the Duval County LID manual because they provide both a conveyance and treatment function and meet the distributed stormwater treatment goals of LID. Figure 3.1-1 shows features of a grassed swale system.

Figure 3.1-1 Cross-Section View of a Grassed Swale System



Grassed conveyance swales provide infiltration capacity that can capture and infiltrate stormwater close to the source of the runoff. When the storm event is too large to be infiltrated, the swale is used to convey the excess runoff to another stormwater management practice, such as a wet detention pond. Grass in the swale helps filter pollutants, increase particulates settling, stabilize soils, and minimize erosion. Swales can be an important component in a stormwater treatment train as they provide water quality improvements and conveyance. Grassed conveyance swales are open conveyance systems and do not include any physical barriers such as swale blocks or raised driveway culverts. Watershed models such as EPA-SWMM5 (http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/) and WinSLAMM (http://winslamm.com/) include components that can be used to model the hydraulics and water quality benefit of grassed conveyance swales. Research published by authors such as Barrett et al. (1998), Deletic & Fletcher (2006), Yousef et al. (1987), and PBS&J (2010) have demonstrated how effective conveyance swales can be at reducing pollutant loading through both infiltration and pollutant-concentration reductions.

The current SJRWMD presumptive criteria for permitting grassed conveyance swales as a stormwater-quality BMP require that a swale percolate either 80% or 100% of the 3-year/1-hour storm depending on the receiving water body. This section provides a methodology for accounting for the water quality improvement of grassed conveyance swales that are not able to infiltrate a sufficient volume to meet the SJRWMD presumptive criteria.

For stormwater quality permitting, a swale that includes a ditch block would be permitted as a linear retention basin. The permitting methodology for these types of systems is not covered in this manual as it is already established by SJRWMD and published in the SJRWMD Applicant's Handbook: Regulation of Stormwater Management Systems (SJRWMD, 2010, page 11-1).

3.1.1.2 Applicability

Water Quantity Control

Grassed conveyance swales will provide some attenuation of peak discharge volumes. However, they will most likely not provide sufficient attenuation to meet SJRWMD water quantity control criteria or the City of Jacksonville Master Stormwater Management Plan special basin criteria.

Water Quality Control

A grassed conveyance swale is usually able to provide a significant reduction in total loads of suspended solids, phosphorus, nitrogen, and metals through runoff-volume reduction and pollutant-concentration reduction. Grassed conveyance swales may not always provide sufficient water quality improvements to meet all SJRWMD water quality requirements. However, despite this limitation they can be a valuable component of the treatment train because they provide both a conveyance and treatment function.

General Feasibility

A grassed conveyance swale is typically used in place of a conventional curb-and-gutter stormwater system and is most widely used within the right-of-way alongside a road shoulder or within a median. Grassed conveyance swales can also be used to convey site runoff within other settings such as residential, commercial, or institutional developments.

Physical Constraints

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

- SHWL – Must be at least 6 inches below the bottom of the swale.
- Slope – Low- to-moderately sloped sites.
- Right-of-way – Sufficient width in the right-of-way to include a swale.

3.1.2 DESIGN CONSIDERATIONS AND REQUIREMENTS

The following criteria are considered **minimum** standards for designing a grassed conveyance swale in Duval County. Consult with SJRWMD to determine whether any variations must be made to these criteria or if additional standards must be followed.

3.1.2.1 General

A grassed conveyance swale should be designed to convey at least the 5-year/24-hour design storm without erosion, scouring, or localized flooding. The average annual pollutant-load reduction for a grassed conveyance swale that is unable to infiltrate the 3-year/1-hour storm can then be calculated using the methods described in this section.

3.1.2.2 Location and Planning

Grassed conveyance swales are generally located within the right-of-way. However, they can also be used as a conveyance feature in other settings such as residential, commercial, or institutional. Grassed conveyance swales are designed for intermittent flow and should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

3.1.2.3 Sizing Requirements

- For maintenance reasons, the swale should have an approximately trapezoidal shape with a bottom width of at least 2 feet to allow mowing.
- The bottom width should be less than 8 feet to avoid forming erosion channels. If the bottom width is greater than 8 feet, a level spreader must be constructed at least every 150 feet along the swale to prevent erosion.
- The side slope should be 3:1 or flatter.
- The longitudinal slope must be between 0.5% and 3%. The slope should allow the swale to drain but not erode.
- The maximum velocity in the swale for the design storms must not exceed the maximum permissible velocities provided in Table B-1.
- All culverts within the swale system should be sized to ensure that the maximum velocity within the culverts does not exceed the maximum permissible velocity for the swale for the design storms because this can result in erosion at the culvert outlet. The appropriate erosion-protection measures should be provided in cases where this maximum permissible velocity is exceeded within a culvert.
- The designer should determine Manning's n considering roughness, flow depth, velocity, and channel geometry.
- Design infiltration rate should be no more than half the field-measured infiltration rate. The infiltration rate should be field-measured at the depth of the swale bottom using a double-ring infiltrometer and should follow the methodology provided in ASTM D3385-09.
- Swales must be designed to maintain the appropriate flooding level of service.
- Off-street parking that can cause rutting or compaction should be prohibited within 3 feet of the top of bank of the swale.

- Swales must not be constructed within 50 feet of a public or private potable water supply well.
- Discharges into the swales should be as distributed along the length of the swale. The maximum contributing area to a point discharge into the swale is 1 acre.

3.1.2.4 Discharge Requirements

Grassed conveyance swales are commonly used as a component of the treatment train and may not have a specific flow-attenuation requirement. However, the complete stormwater treatment system for the site must meet SJRWMD and City of Jacksonville water-quantity discharge requirements.

3.1.2.5 Recovery Requirements

All standing water must be recovered through surface discharge or percolation in less than 72 hours under SHWL conditions with average antecedent soil moisture conditions in the soil profile. An appropriate Florida-registered and -licensed professional must analyze discharge from the swale including percolation and surface flow. Site-specific geotechnical data must be used to determine percolation. For guidance on the number of borings, refer to SJ93-SP10 (SJRWMD, 1993).

3.1.2.6 Water Quantity Credits

Swale systems may provide some attenuation of peak discharge. This attenuation can be demonstrated using a hydrologic or hydraulic model that has been accepted by SJRWMD.

3.1.2.7 Water Quality Treatment Requirements/Credits

For permitting as a stormwater BMP, SJRWMD requires that a grassed conveyance swale discharging to a Class I watershed, a Class II watershed, or an Outstanding Florida Water or a Class III watershed restricted for shellfish harvesting be designed to percolate all runoff from the 3-year/1-hour storm and that swales discharging to a Class-III-receiving water body be designed to percolate 80% of the runoff from the 3-year/1-hour storm. However, most swale systems are intended to be part of a treatment train in which 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 percolated in the swale system and the pollutant-concentration reductions that occur within the grassed conveyance swale.

For those systems that cannot percolate the required volume of the 3-year/1-hour storm, the percentage of the average annual runoff volume percolated in the swale system can be estimated using one of the following methods:

- Continuous simulation – A continuous simulation of the percolation that occurs in the system using a hydrologic and hydraulic model accepted by SJRWMD and a long-term rainfall record (at least 30 years) for Duval County.
- BMPTRAINS model – The Stormwater BMP Treatment Trains model (http://www.stormwater.ucf.edu) may be used to determine the percentage of the average annual volume of water percolated or retained by the grassed conveyance swale. This model requires that the drainage area, swale dimensions, swale length, and infiltration rate are known. Reduction factors for high water table conditions must be used where applicable and are discussed below.
- Other Accepted Methodology – Any methodology accepted by SJRWMD for calculating the long-term average-annual performance of grass conveyance swales.

- The BMPTRAINS model assumes that the SHWL is at least 24 inches below the bottom of the swale. In situations where the SHWL is between 24 and 6 inches below the bottom of the swale, a reduced average-annual performance must be calculated by multiplying the BMPTRAINS-determined average-annual performance by the appropriate reduction factor in Table 3.1-1. This table provides a range of performance-reduction factors that are applied based on the design soil infiltration rate.

Table 3.1-1 Performance Reduction Factors for Average Annual Percolation Volume for Grassed Conveyance Swales in Duval County for SHWL between 24-inch and 6-inch of the Swale Bottom

Design Soil Infiltration Rate*	Average Annual Performance Reduction Factors**
< 1 inch/hour	0.95
1 to 5 inches/hour	0.75
> 5 inches / hour	0.60

*Field determined using double-ring infiltrometer.
**Developed for this manual from multiple 30-year continuous simulations of a swale in Duval County under various high water table conditions in EPA-SWMM5. It was found that percolation performance under high water table conditions was sensitive to soil hydraulic conductivity.

In addition to reducing the volume of runoff from a site, swales can reduce pollutant concentrations. Accounting for this reduction should be discussed with SJRWMD regulatory staff at a pre-application meeting. The reduced pollutant concentration of stormwater from a swale may also have an effect on the performance of downstream BMPs such as detention ponds.

An additional pollutant-load reduction to account for reduced concentrations should only be considered for grassed conveyance swales with a contributing-area-to-length ratio less than or equal to 0.5 acre/100 feet. This pollutant-concentration reduction can be determined from Table 3.1-2 or another reference accepted by SJRWMD and City of Jacksonville and can only be considered after the load reduction through percolation has been accounted for. Future monitoring of swale nutrient-removal efficiencies by the City of Jacksonville will be used to refine Table 3.1-2.

Table 3.1-2 Average Annual Concentration Reduction in a Grassed Conveyance Swale

Pollutant	Average Annual Concentration Reduction
TN	30%*
TP	16%*
TSS	78%*

*1st Quartile of published average concentration reductions from Barret et al. (1998), Deletic & Fletcher (2006), Yousef et al. (1987), and PBS&J (2010).

The average annual removal efficiency of the swale is assumed to be equivalent to the fraction of the average annual runoff retained and percolated by the swale system and the fraction of the average annual load reduction due to decreased pollutant concentrations. Equation 3.1-1 calculates the average annual effectiveness of the swale:

$$E_{tot} = E_{perc} + (1-E_{perc})E_{conc} \quad (3.1\text{-}1)$$

Where: E_{tot} = Total average annual removal efficiency of the swale (decimal fraction)
E_{perc} = Average annual runoff retained and percolated by the swale (decimal fraction)
E_{conc} = Average annual concentration reductions (decimal fraction)

3.1.2.8 Maintenance Access

Access to the swale area must be provided at all times for inspection, maintenance, and landscaping upkeep, and sufficient space must exist around the swale system to allow accumulated surface sediments to be removed if the system fails inspection.

3.1.2.9 Safety Features

Grassed conveyance swales must meet all Florida Department of Transportation and City of Jacksonville safety requirements.

3.1.2.10 Landscaping

Vegetation enhances the performance and function of grassed conveyance swales. Turf grass in the swale should be quickly established and be weed-resistant and tolerant of short-term ponding and periods of low soil moisture. The unpaved contributing area must be well-vegetated to minimize erosion and sediment inputs to the swale system.

3.1.3 Design Procedure

3.1.3.1 Design Steps

- Step 1 – Determine if the development site and conditions are appropriate for a grassed conveyance swale. Consider the Application and Site Feasibility Criteria in Sections 3.1.1.2 (Physical Constraints) and 3.1.2.2 (Location and Planning).
- Step 2 – Follow the SJRWMD design criteria and guidelines for swale systems to determine if the swale is able to percolate the required volume during the 3-year/1-hour storm.
- Step 3 – If the swale does not meet the SJRWMD requirements in Step 2, use the BMPTRAINS model (http://www.stormwater.ucf.edu/) for grassed conveyance swales to determine the average-annual pollutant load reduction:
    - *Step 3a* – Determine the drainage area and its runoff response characteristics such as DCIA and Non-DCIA CN values.
    - *Step 3b* – Determine swale dimensions. Size bottom width, depth, length, and slope necessary to convey the design storm.
        - The maximum velocity should be determined from Table B-1.
        - If possible the bottom width should be between 2 and 8 feet.
        - Side slopes should be 3:1 or flatter.
        - Manning's n should be determined considering swale geometry, roughness, flow depth, and flow velocity.
    - *Step 3c* – Find the average annual treatment efficiency from BMPTRAINS model or other accepted methodology. This efficiency is the average annual pollutant-load reduction due to percolation for each constituent.
    - *Step 3d* – Calculate the total average annual pollutant-load reduction using Table 3.1-1 if required and Table 3.1-2.

- *Step 4* – If necessary determine the effectiveness of the entire “treatment train” by accounting for the effectiveness of all stormwater BMPs on a site. Additional stormwater treatment capacity may need to be designed to ensure that the system meets the water quality and quantity requirements for the site.

3.1.3.2 Design Example

The following example is intended to guide an applicant through designing a grassed conveyance swale.

Assume a residential project in Jacksonville is discharging to the St. Johns River between Julington Creek and the mouth of the river, which is classified as an OFW, with the following site characteristics:

- Drainage area = 10 acres.
- Post-development runoff coefficient (C_p) = 0.4.
- *Tc* = 20 minutes; *S* = 3%.
- Fillable Porosity (f) = 0.3.
- Field infiltration rate determined by double-ring infiltrometer tests at the depth of the swale bottom and divided by 2 to account for air entrapment (K_{vs}) = 36 in/hr.
- Factor of Safety *(FS)* = 2.0.
- Height of swale bottom above seasonal high groundwater table (h_b) = 4 feet.
- Rectangular project site with dimensions of length = 660 ft and width = 660 feet.
- Three streets each 600 feet long with swales on both sides.

The objective is to design a swale system to percolate all or part of the required treatment volume that meets the capacity and velocity requirements for swales.

Design Calculations

- *Step 1* – Review the development site and conditions were reviewed – Sections 3.1.1.2 (Physical Constraints) and 3.1.2.2 (Location and Planning) – and determine if appropriate for a grassed conveyance swale.
- *Step 2a* – Determine the Sustained Peak Runoff Rate (Q_P) and Volume of Runoff (V_R).

  For swales discharging to an OFW, SJRWMD rules requires that if a swale will be used as the only stormwater practice on site, the swale must be able to percolate 100% of the runoff from the 3-year, 1-hour storm. In Duval County, grassed conveyance swales that do not percolate all the required treatment volume can be used for partial treatment of stormwater.

  From the Florida Department of Transportation IDF Curve (FDOT, 1987) for Zone 4 (Jacksonville), the average intensity (*i*) for the 3-year, 1-hour storm is 2.4 in/hr.

  Q_p is expressed as:

$$Q_P = C_p\, I_D\, A \qquad (3.1\text{-}2)$$

Where: Q_P = Peak runoff rate from the 3-year, 1-hour rainfall intensity (*cfs*)

I_D = Average rainfall intensity for a 1-hour duration (*in/hr*)

A = Drainage area (*acres*)

Q_P = (0.4) 2.4 *in/hr* (10 *ac*) = 9.6 *cfs*

The volume of runoff (V_R) is found by using Equation 3.1-3:

$$V_R = Q_P D \qquad (3.1\text{-}3)$$

Where: V_R = Volume of runoff (ft^3)

D = Rainfall duration (*min*)

V_R = (9.6 *cfs*) (60 *min*) (60 *sec/min*) = 34,560 ft^3

Since each swale serves approximately an equal drainage area and project land use, the peak runoff rate (Q_P) per swale represents a more realistic flow for the design of the treatment function for the swale. The peak runoff flow rate (Q_P) per swale is:

Q_P *per swale = 9.6 cfs / (3 streets)(2 swales/street)= 1.6 cfs*

- *Step 2b* – Select swale dimensions and determine flow depth and percolation area. Assume a trapezoidal shaped swale with side slopes of 4:1 and a bottom width (*b*) of 2 feet. From Figure B-1:

$Z = e/d = 4$ (defined in Figure B-1)

Cross-sectional area (A_{cs}) $= Z\, d^2 + bd = 4d^2 + 2d$

Hydraulic Radius $(R) = (Z\, d^2 + bd) / (b + 2d\, (Z^2+1)^{1/2}) = (4d^2+2d)/(6+6d)$

Where: d = Normal depth of flow in the channel (ft)

Using Figures B-2 and Table B-2 to determine Manning's roughness coefficient (*n*).

From Table B-2 for Bahia grass, assume the grass is a good stand and mowed. Therefore, the retardance class = Class D and *n* = 0.04 for design of the swale treatment capacity. A more overgrown condition (retardance class = B and *n* = 0.077) should be considered for conveyance and level of service flood protection design.

To solve for the normal depth (*d*), first rearrange the equation for the flow capacity of an open swale:

$$Q = (1.49/n)(R^{2/3})(S^{1/2})(A_{cs})$$

to give:

$$R^{2/3} A_{cs} = Q\, n / (1.49\, S^{1/2})$$

Substituting the above values of *Q*, *n*, and *S*:

$$R^{2/3} A_{cs} = 1.6\,(0.04)/(1.49\,(0.03)^{1/2}) = 0.25$$

Trial #1: Assume d = 0.5 ft. A_{cs} is:

$A_{cs} = 4\ (0.50\ ft)^2 = 1.0\ ft^2$
$R = (4(0.5)^2+2(0.5))/(6+6(0.5)) = 0.327\ ft$
$R^{2/3} A_{cs} = (0.327)^{2/3} 1.0 = 0.47$

Since 0.47 ≠ 0.25, try another value for d.

Trial #2: Assume d = 0.40 ft

$A_{cs} = 4\ (0.40\ ft)^2 = 0.64\ ft^2$
$R = (4(0.40)^2+2(0.40))/(6+6(0.40)) = 0.27\ ft$
$R^{2/3} A_{cs} = (0.27)^{2/3}\ 0.64 = 0.27$

Since 0.27 ≈ 0.25, the value of d = 0.40 ft is acceptable.

Also from Figure B-1, the wetted perimeter (P) is:

$P = 2d(1+Z^2)^{1/2} = 2\ (0.40)(1+4^2)^{1/2} = 1.79\ ft$

The total length of swales, L = (3 *streets*) (2 *swales / street*) (600 *ft / swale*) = 3,600 *ft*

The total percolation area (A_b) can be determined:

$A_b = \mathrm{L}\ P = (3600\ ft)\ 1.79\ ft = 6440\ ft^2$

The percolation area (A_b) per swale is:

A_b per swale = (600 *ft*) 1.79 *ft* = 1073 ft^2 per swale

- *Step 2c* – Check for lateral saturated infiltration (see SJRWMD Handbook Section 26 for a complete description of infiltration processes).

Volume percolated under vertical unsaturated flow (V_u) is determined from Equation 3.1-4:

$$V_u = A_b\ f\ h_b = 6{,}440\ ft^2\ (0.3)\ 4\ ft = 7{,}728\ ft^3 \quad (3.1\text{-}4)$$

Where: V_u = Volume of water required to saturate the soil below the swale

h_b = Height of swale bottom above the ground water table

f = Fillable porosity (generally 0.2 to 0.3)

Since $V_u < V_R$ percolation will not occur entirely under vertical unsaturated flow conditions, an analysis of lateral saturated infiltration and/or an open channel routing analysis using a SJRWMD-accepted groundwater mounding analysis or hydraulic routing model will be required to demonstrate that the swale can recover the treatment volume (through percolation or surface discharge) within 72 hours.

For this design example, we assumed that we were able to use PONDS to demonstrate that the swale was able to recover the treatment volume within 72 hours.

- *Step 2d* – Calculate the peak infiltration flow rate (Q_{iP}).

  The unsaturated vertical hydraulic conductivity (K_{vu}) is found by the following:

  $$K_{vu} = \frac{2\,(36\ in/hr)}{3} = 24\ in/hr$$

  The design infiltration rate (I_d) is:

  $$I_d = \frac{24\ in/hr}{2} = 12\ in/hr$$

  Where 2 is a factor of safety recommended by the SJRWMD.

  The peak infiltration rate (Qi_P) per swale is determined with the infiltration area (A_b) per swale = 1,073 ft^2:

  Qi_P per swale = 12 *in/hr* (1,073 ft^2 per swale) (1 ft/12 in) (1 hr/60 min)

  Qi_P per swale = 17.9 ft^3/min = 0.30 ft^3/sec per swale

- *Step 2e* – Calculate the volume of water infiltrated (V_I) per swale and compare to the required infiltration volume.

  Using $V1 = QiP\,(D + Tc - (Tc*QiP)/Qp))$ *(3.1-5)*

  Where: Tc = 20 min; D = 60 min; Qi_P = 17.9 ft^3/min; and Q_P = 1.6 ft^3/sec:

  V_1 per swale = 17.9 ft^3/min (60 min + 20 min - (20 min(17.9 ft^3/min)/((1.6 ft^3/sec)(60 sec/min))

  V_I per swale = 1,365 ft^3 per swale

  Total V_I = 1,365 ft^3 per swale x 6 swales = 8,191 ft^3

  Required percolation volume for discharges to OFW receiving waters is 100% of the 3-year/1-hour runoff volume (V_R):

  The required infiltration volume = V_R = 34,560 ft^3

  Since the swale can only infiltrate 23.7 % (V_I) of the runoff (V_R) from the 3-year/1-hour storm, the design is inadequate as the only stormwater quality practice on the site.

- *Step 3* – Use the BMPTRAINS model for grassed conveyance swales to determine the average-annual pollutant-load reduction.
  - Duval County is in Meteorological Zone 4.
  - The drainage area is 10 acres with 3.3 acres draining to each street.
  - Assume that the site has a non-DCIA CN of 65 and with 45% DCIA.
  - The swale length is 600 feet.
  - Highway length is 600 feet.

- Highway width—including parking and shoulders—contributing to each swale is 34 feet.
- The average width of the pervious area draining to the swale is 46 feet.
- Swale slope is 0.03 foot/foot.
- Swale top width for flood conditions is 12 feet.
- Manning's n is 0.04.
- Soil infiltration is 12 inches/hour.
- Swale side slope 4:1.
- No ditch blocks are proposed for the swale since it is primarily for conveyance

The BMPTRAINS model shows that 84% of the average annual runoff volume is percolated by the swale. Since the SHWL is more than 2 feet below the bottom of the swale, the efficiency of the swale does not need to be adjusted.

In the design example, the ratio of the contributing area to the swale length is 0.28 acre/100 feet, which is less than 0.5 acre/100 feet noted in Section 3.1.2.7. Therefore, additional pollutant removal through concentration reductions (Table 3.1-2) can be considered. Using Equation 3.1-1 would result in the following average annual swale effectiveness:

- TN = 0.84 + ((1 – 0.84) x 0.30) = 0.89
- TP = 0.84 + ((1 – 0.84) x 0.16) = 0.87
- TSS = 0.84 + ((1 – 0.84) x 0.78) = 0.96

If the SHWL had been between 24 and 6 inches from the bottom of the swale, the percolation effectiveness (E_{perc}) of the system would have been adjusted using Table 3.1-1. Since the soil infiltration rate is 12 inches/hour, the reduction factor is 0.6 and the swale effectiveness would be calculated as follows:

- E_{perc} = 0.84 x 0.6 = 0.50

Considering the additional pollutant removal through concentration reductions (Equation 3.1-1) would result in the following average annual effectiveness if the SHWL had been between 24 and 6 inches from the bottom of the swale:

- TN = 0.50 + ((1 – 0.50) x 0.30) = 0.65
- TP = 0.50 + ((1 – 0.50) x 0.16) = 0.58
- TSS = 0.50 + ((1 – 0.50) x 0.78) = 0.89

- *Step 4* – If we assume that due to land use changes the overall stormwater system needs to provide a 93% reduction in the annual load of TN, TP, and TSS to meet the "net improvement" required for discharging to an impaired waterbody, then a downstream stormwater BMP will be required to further reduce the TN and TP load.

- The following calculations demonstrate how a downstream stormwater management system could be sized to meet water quality standards given the swale with SHWL more than 2 feet below the bottom on the swale.

  Assuming that a wet detention system is the most appropriate downstream stormwater management system to provide flood control and additional water quality improvements, then the overall stormwater system effectiveness can be calculated using the following equation:

  $E_{tot} = E_{swale} + (1 - E_{swale})E_{det}$

  Where: E_{tot} = Annual removal efficiency of the swale and detention pond combination (decimal fraction).

  E_{swale} = Annual removal efficiency of the swale that was calculated in Step 3 (decimal fraction).

  E_{det} = Annual removal efficiency of the detention pond (decimal fraction).

  See Figure 1.1 for a graphical representation of the above calculations.

  Therefore:

  Edet = (Etot - Eswale) / (1 - Eswale)

  TN: E_{det} = (0.93 - 0.89) / (1 - 0.89) = 0.36

  TP: Edet = (0.93 - 0.87) / (1 - 0.87) = 0.46

  Therefore:

  The wet detention system will need to provide at least a 36% reduction in annual TN loading and a 46% reduction in annual TP loading.

  The Florida Department of Environmental Protection and Water Management Districts' Environmental Resource Permit Stormwater Quality Applicant's Handbook (March 2010 – Draft) provides the following equations for calculating removal efficiency of TP and TN in a wet detention pond given a residence time (t_d):

  $TP = 44.53 + 6.146*\ln(t_d) + 0.145*(\ln(t_d))^2$

  $TN = (43.75*t_d) / (4.38 + t_d)$

  Solving for t_d to get a TP removal efficiency of 46% gives t_d = 1.2 days

  Solving for t_d to get a TN removal efficiency of 43% gives t_d = 20.3 days.

  Therefore, the wet detention system should be sized to provide a residence time greater than 20.3 days.

- The size of the wet detention system can then be calculated using the following:

  Treatment Volume

  1-inch runoff: TV = (10 ac x 1 inch) / 12 = 0.83 acre-feet

2.5 inch over impervious area: TV = (4.5 acres x 2.5 inches) / 12 = 0.94 acre-feet

Therefore, the required treatment volume is 0.94 acre-feet.

Permanent Pool Volume:

PPV = (DA x C x R x RT) / (WS x 12)

Where: DA = Drainage area to pond (acre).

C = Runoff coefficient.

R = Wet-season rainfall depth (inches) (Rao et al., 1990).

RT = Residence Time (days).

WS = Length of wet season (153 days).

FR = Average Flow Rate (acre-feet/day).

PPV = Permanent Pool Volume (acre-feet).

The results of the BMPTRAINS model in Step 3 show that 84% of the average annual runoff into the swales is percolated. Therefore, the effective runoff coefficient for the pond can be estimated to be 0.16.

PPV = (10 x 0.16 x 30 x 20.3) / (153 x 12) = 0.53 acre-foot

Therefore, the required permanent pool to achieve a 20.3 day residence time is 0.53 acre-foot.

It should be noted that the 93% load reduction achieved by this treatment train could not have been achieved by a wet detention system alone. The combination of a grassed conveyance swale and wet detention was crucial in meeting the net improvement requirement.

3.1.4 CONSTRUCTION

The following construction procedures are required to avoid degrading the swale's infiltration capacity:

- Verify the location and dimensions of the swale system on site before its construction. All design requirements including swale dimensions and distances to foundations, septic systems, and wells need to be verified.
- Clearly mark the locations of swales at the site to prevent unnecessary vehicular traffic across the area causing soil compaction.
- Excavate using by lightweight equipment to minimize soil compaction. Tracked, cleated equipment does less soil compaction than equipment with tires.
- Ensure that lateral and longitudinal slopes meet permitted design requirements and will not erode due to channelized flow or excessive flow rates.
- Do not conduct final grading and planting of the swale until the adjoining areas draining into the swale are stabilized. Any accumulation of sediments that occurs must be removed during the final stages of grading. The bottom should be tilled to produce a highly porous surface.

- Ensure that measures are in place to divert runoff while vegetation is being established on the side slopes and bottom of the swale. If runoff cannot be diverted, vegetation must be established by staked sodding or by erosion control blankets or other appropriate methods.

- Ensure that the vegetation used in the swale is consistent with values used for Manning's n in the design calculations.

An applicant may propose alternative construction procedures to ensure that the design infiltration rate of the constructed and stabilized swale system is met provided it is accepted by the City and SJRWMD.

3.1.5 Operation and Maintenance

3.1.5.1 Inspection

The operation and maintenance entity is required to have the total surface water management system inspected by the appropriate Florida-registered and -licensed professional to ensure that the system is properly operated and maintained. The inspections must be consistent with ERP requirements regarding inspection of the stormwater system. If applicable, the City of Jacksonville MS4 NPDES permit inspection and maintenance schedule for grass treatment swales (dry) should also be followed (Appendix F). Inspection must be documented and the documentation must be retained by the inspecting party for reference if necessary. At a minimum the following should be inspected:

- Inflow/outflow points for any clogging.

- Swales for standing water, erosion, or gullying.

- Swales for any obstructions that may have been constructed in the swale such as raised driveway culverts or fences.

- Swales for mosquito-breeding areas such as where standing water occurs more than 72 hours after rainfall or where cattails or other invasive vegetation becomes established.

3.1.5.2 Maintenance

System maintenance should include:

- Maintaining healthy vegetative cover to prevent erosion of the swale bottom or side slopes.

- Maintaining grass height of 4 to 6 inches and removing grass clippings from the swale.

- Replacing soil and vegetation where needed when erosion is evident.

- Removing trash and debris as needed.

- Aerating, tilling, or replacing topsoil as needed to restore the percolation capability of the soil. Reestablishing vegetation within 60 days of disturbance. Protecting soil surface from erosion until vegetation is reestablished.

- Removing sediment from inflow and outflow systems as needed.

- Stabilizing any upstream erosion as needed.

- Removing and replacing any dead or severely damaged vegetation.

- Eliminating mosquito-breeding habitats.

3.1.5.3 Additional Maintenance Considerations and Requirements

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

3.1.6 REFERENCES

Barrett M.E., P.M. Walsh, J.F. Malina Jr., R.J. Charbeneau. 1998. *Performance of Vegetative Controls for Treating Highway Runoff.* Journal of Environmental Engineering 124 (11), 1121-1128.

Deletic A. and T.D. Fletcher, 2006. *Performance of grass filters used for stormwater treatment, a field and modeling study*. Journal of Hydrology 317, 261-275.

Florida Department of Environmental Protection and Water Management Districts. 2010. *Draft Environmental Resource Permit Stormwater Quality Applicant's Handbook*.

PBS&J. 2010. *EMC Monitoring in Support of Pollutant Load Modeling*. Prepared for Sarasota County and Southwest Florida Water Management District.

Rao D. V., S. A. Jenab, and D. A. Clap. 1990. *Rainfall Analysis for Northeast Florida Part V: Frequency Analysis of Wet Season and Dry Season Rainfall*. Technical Publication SJ 90-3. St. Johns River Water Management District, Palatka, Florida.

St. Johns River Water Management District (SJRWMD). 2010. *Applicant's Handbook: Regulation of Stormwater Management Systems Chapter 40C-42, FAC.*

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

Yousef Y.A., T. Hvitved-Jacobsen, M.P. Wanielista, and H.H. Harper. 1987. *Removal of Contaminants in Highway Runoff Flowing Through Swales.* The Science of the Total Environment 59, 391-399.

3.2 SHALLOW BIORETENTION

Key Considerations	**Practice Intent:** ▪ Capture stormwater runoff and promote evapotranspiration and infiltration of the captured runoff close to source. **Design Criteria:** ▪ Typically the tributary area is 2 acres or less. Treatment area consists of grass filter, surface ponding area, top dispersion layer (mulch or similar), planting media layer with vegetation, and optional nutrient-sorption layer. **Advantage/Benefits:** ▪ Applicable to small tributary areas. ▪ Good retrofit capability. ▪ Can be an aesthetic feature. **Disadvantages/Limitations:** ▪ Requires landscaping. ▪ High water table can reduce effectiveness. **Maintenance Requirements:** ▪ Inspect and repair/replace treatment area components. ▪ Remove trash, litter, and sediment. **Monitoring/Record Keeping:** ▪ Avoid fertilizer applications but if used maintain a record of fertilizer application. ▪ Conduct embedded ring infiltration tests every 5 years. **Recovery:** ▪ Surface ponding area must be recovered within 72 hours.
Pollutant-Removal Potential	**H/M** **Total Suspended Solids** **H/M** **Nutrients**—Total Phosphorus/Total Nitrogen **H/M** **Metals**—Cadmium, Copper, Lead, and Zinc **H/M** **Pathogens**—Coliform, Streptococci, E.Coli
Stormwater Management Suitability	☒ **Water Quality** ☐ **Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Well suited **High-Density/Ultra-Urban:** Well suited **Tributary Area:** Typically 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible. **Shallow Water Table:** SHWL should be a minimum of 6 inches below the bottom of the planting media or nutrient-sorption layer. **Soils and Media:** Planting and sorption media must meet specified criteria; well-drained native soil is preferable.
Other Considerations:	Use of native plants is highly recommended.

L—Low, **M**—Moderate, **H**—High

3.2.1 General

3.2.1.1 Overview and Intent

Bioretention areas are shallow depressions used as structural stormwater controls to capture stormwater runoff that promote evapotranspiration and infiltration. Within the bioretention area, soils, mulch, planted vegetation, and optional nutrient-sorption media 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 and evaporation, thereby reducing runoff and recharging groundwater. Figure 3.2-1 shows features of a bioretention system.

3.2.1.2 Applicability

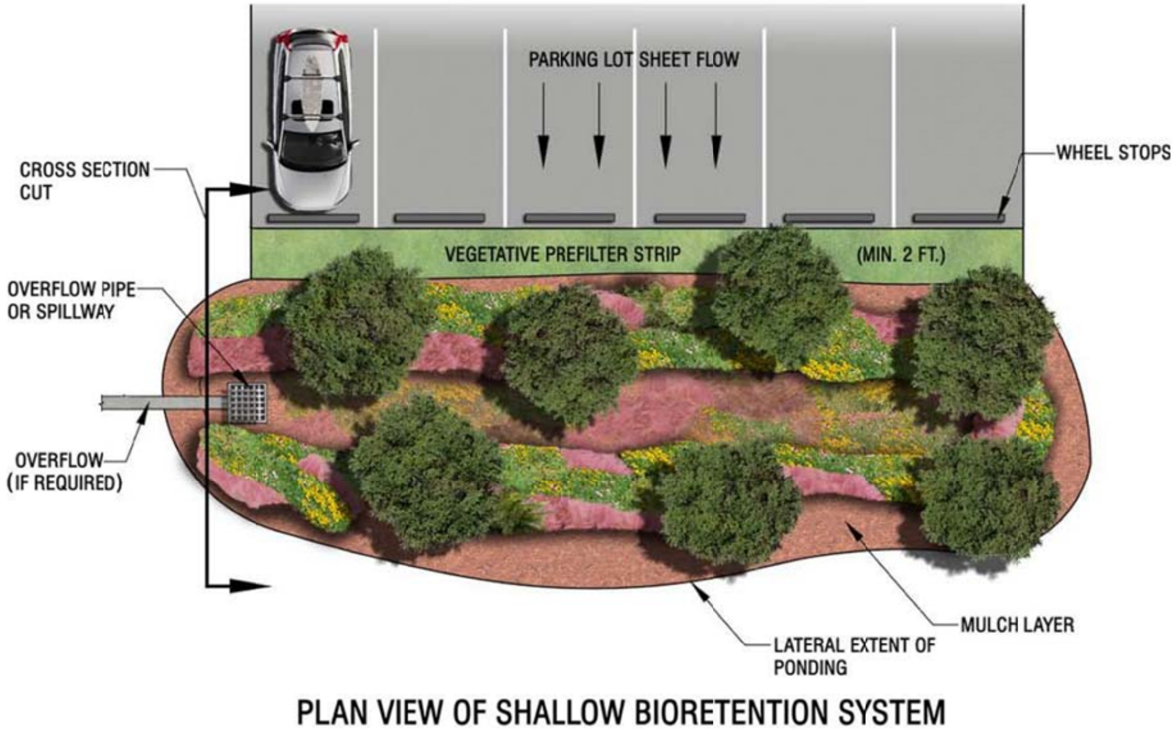
3.2.1.3 Water Quantity Control

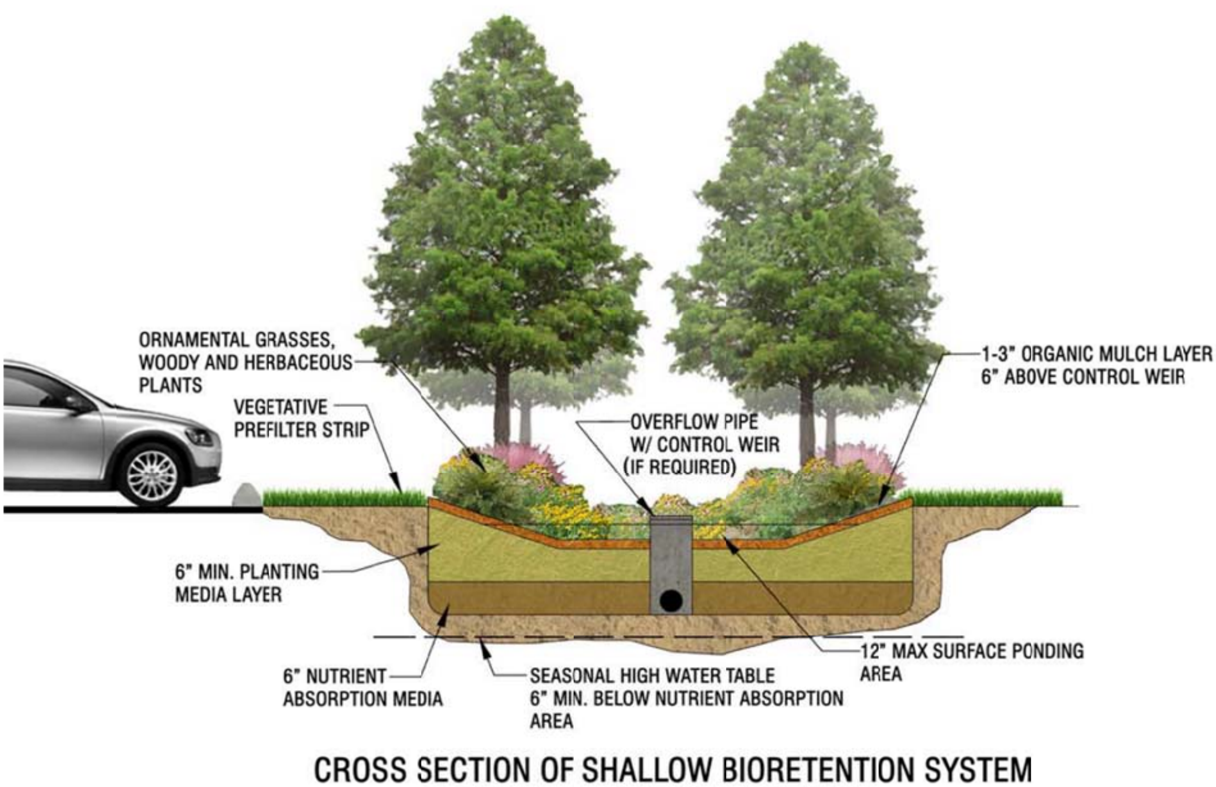
Bioretention systems are designed primarily to address stormwater quality. Bioretention systems provide limited attenuation of peak flows and most likely will not provide sufficient storage capacity to meet City of Jacksonville and SJRWMD water quantity control criteria. Bioretention provides a retention volume related to average annual volume capture efficiency. The retention volume is typically not large enough to account for the required total average annual capture volume, but when used with other BMPs the bioretention may provide a cost-effective solution.

3.2.1.4 Water Quality Control

Bioretention systems can be more effective for reducing the concentration of pollutants in the water than conventional retention systems. The removal is due to the increased interaction of stormwater runoff with select sorption soil, frequently called media, microbes, and vegetation, thus enhancing biogeochemical processes. Bioretention areas improve the water quality of water being discharged from the bioretention area. The discharge is to the groundwater for retention systems.

Figure 3.2-1 Plan and Cross-Section Views Illustrating 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 to use near impervious areas such as roadway medians, parking lot islands, and swales. Bioretention systems are also well suited for treating runoff from some pervious areas, such as recreational fields or landscaped areas, where the soil is stabilized and sediment washoff is relatively low. Bioretention systems may also be used to treat roof runoff. However, bioretention systems are generally not suitable for regional stormwater control because of the increased volume of water in regional systems.

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:

- Drainage Area – Recommended drainage area that is typically 2 acres or less to be consistent with the goal of treating runoff as close to the source as possible.
- SHWL – Must be at least 0.5 foot below the bottom of the surface ponding area.
- Soils – Relatively high hydraulic conductivity in the native soils results in more effective stormwater runoff capture.

3.2.2 Design Considerations and Requirements

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

3.2.2.1 General

A shallow bioretention should address the following (see Figure 3.2-1):

- *Prefilter Strip* – Where feasible, a prefilter or grass channel strip between the contributing tributary area and the surface ponding area to capture coarse sediments and reduce sediment loading to the ponding area. The applicant may provide other measures, such as a stilling area within the bioretention facility, to minimize the sediment loading 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.
- *Surface Ponding Area* – An area that provides temporary surface storage (to a maximum depth of 12 inches) for captured runoff before infiltration into the planting media and evapotranspiration.
- *Dispersion Material Such as Mulch or Rock Layer* – A 1-to-3-inch layer between surface ponding and planting media, with benefits including attenuation of heavy metals, reduced weed establishment, regulation of soil temperature and moisture, and addition of organic matter to the soil. Pre-emergent herbicides may be applied sparingly as needed to further minimize weed establishment.
- *Planting Media Layer* – 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.

- *Nutrient-Sorption Media* – A 6-inch layer below the planting media or incorporated within the plant media to a depth of 12 inches, which promotes pollutant removal through sorption and denitrification. Details are discussed in Section 3.2.2.3. This layer is currently not required.

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

- *Energy-Dissipation Mechanism* – For concentrated flow, a structure that reduces runoff velocities, distributes flow, and reduces disturbance of the mulch layer.

- *Overflow Pipe or Spillway* – If needed, an outlet structure for runoff in excess of the surface storage capacity to bypass the system. The discharge invert should be set no higher than 12 inches above the bottom of the surface ponding area. Conveyance of the excess runoff should include downstream erosion-control measures if necessary.

3.2.2.2 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 aesthetics 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.

3.2.2.3 Sizing Requirements

Prefilter Strip

- The prefilter strip design will depend on topography, flow velocities, volume entering the buffer, and site constraints. Incorporating a filter strip into a retrofit design may be more difficult than new development. The filter strip must have a minimum length of 2 feet in the direction of flow.

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

Surface Ponding Area

- The maximum ponding depth must be less than 12 inches below the overflow structure or top of bioretention cell.

- The recovery time must be less than 72 hours under SHWL conditions.

Dispersion Layer

- The surface dispersion or mulch layer must be 1 to 3 inches deep and cover the surface of the basin to above the expected high water line.

- For continuing maintenance, the depth must never exceed 4 inches so that soil aeration is not reduced.

- Organic mulch is preferred due to its favorable pH, improved microbial activity, and slower decomposition rate. Examples of acceptable mulches are those made from melaleuca or eucalyptus trees. Inorganic mulches such as rocks or recycled rubber may also be used.

- 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 Media Layer

- The planting media layer must be at least 6 inches thick.
- The media density should be no greater than 70 pounds/cubic foot dry and contain at most 10% organics.
- Clay content should be between 3 and 5%.
- Planting media pH should reflect an optimum range for the plants.
- Planting media organic matter content must be between 3% and 10% by volume.
- The planting media must be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches in size.

Nutrient-Sorption Layer

Although currently not required, a nutrient-sorption layer should typically meet the following requirements:

- The nutrient-sorption layer should be at least 6 inches thick or mixed within the plant media mix.
- The unit weight of layer media should be more than 80 pounds per cubic foot when dry.
- Less than 20% of the particles in the layer media should pass the #200 sieve.
- The material should not contain shale.
- The media water-holding capacity should be at least 30% as measured by porosity.
- At the specified unit weight noted above, the vertical permeability must be at least 0.08 inch per hour but less than 0.25 inch per hour.
- The media must have an organic content of at least 5% by volume. The organic content must be evenly distributed throughout the layer.
- The media pH should be between 6.5 and 8.0.
- The concentration of soluble salts should be less than 3.5 g (KCL)/L.
- The sorption capacity of the sand should exceed 0.005 mg OP/mg media.
- The residual moisture content should exceed 50% of the porosity.

3.2.2.4 Discharge Requirements

The bioretention system is primarily a water quality treatment system and does not normally need to meet any specific discharge requirements. However, for online systems an overflow structure and non-erosive overflow channel should 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 SJRWMD and City of Jacksonville water quantity discharge requirements.

3.2.2.5 Recovery Requirements

The surface ponding volume must be recovered in less than 72 hours under SHWL conditions.

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).

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

3.2.2.6 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:

- Calculate the CN for the bioretention area and include this in the area-weighted CN for the entire site.
- Explicitly model the hydraulic functioning of the bioretention system and its overflow control structure.

3.2.2.7 Water Quality Treatment Requirements/Credits

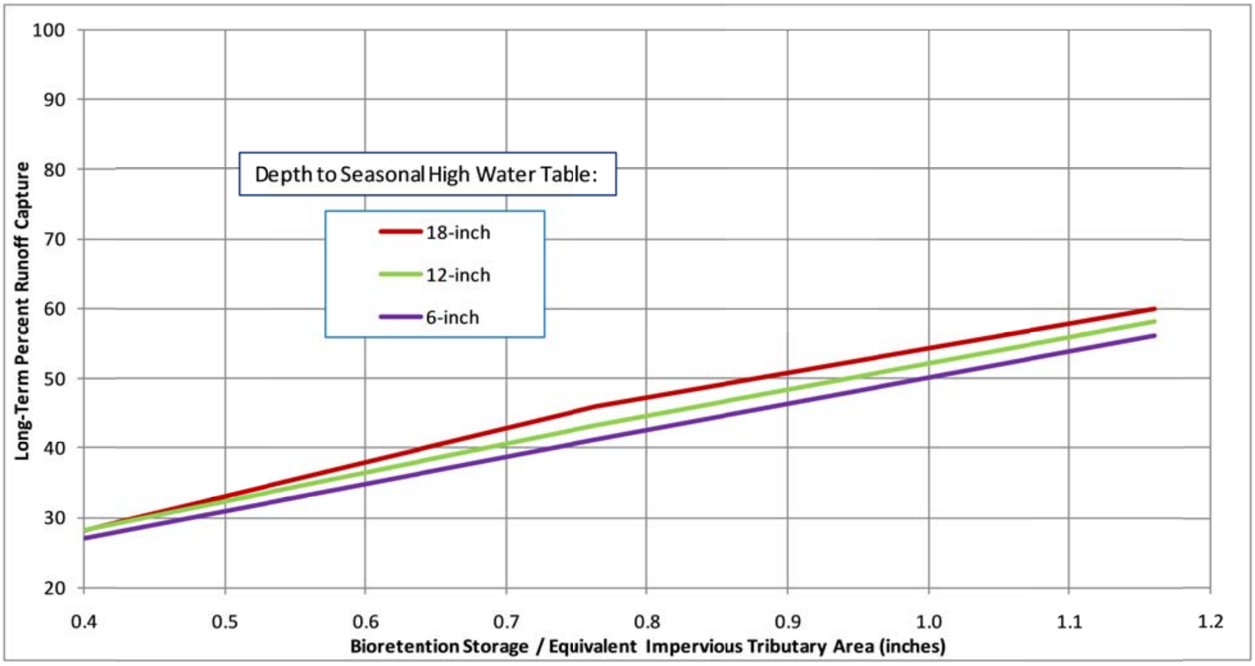
A specific treatment effectiveness can be calculated for a storage volume within a bioretention system. These systems are typically part of a treatment train, where each practice in the train provides incremental water quality benefits. The level of treatment that can be expected from these systems is based on the average annual volume of water captured and infiltrated by the bioretention system. The percentage of the average annual runoff volume captured by the bioretention system must be estimated using one of the following methods:

- *Continuous simulation* – A continuous simulation of the bioretention system using an applicable long-term rainfall record (at least 30 years).
- *BMPTRAINS* – The Stormwater BMP Treatment Trains BMP model (http://www.stormwater.ucf.edu/) can be used to evaluate runoff capture based on the principles of the Draft Statewide Stormwater Rule. Results using BMPTRAINS should be equivalent to results taken from Appendix D, which relates mean annual mass removal to retention storage for the development site The BMPTRAINS model is used when the SHWL is at least 24 inches below the bottom of the bioretention surface storage.
- *Design Curve* – Figure 3.2-2 may be used to determine the percentage of the average annual stormwater runoff captured by the bioretention system when the SHWL is between 6 and 24 inches below the bottom of the bioretention surface storage. When using Figure 3.2-2, the depth of the SHWL below the bottom of the swales should be rounded down to the nearest 6 inches. The figure requires that the equivalent impervious area (EIA) and storage volume are known. The EIA is equal to the mean annual runoff coefficient (C_{ma}) (Table A-1) of the tributary area multiplied by the tributary area. C_{ma} is the mean annual runoff coefficient that can be used to estimate the fraction of rainfall that becomes runoff from the tributary on an annual basis. When Table A-1 is used, a DCIA should be treated as 100% impervious rather than having a CN of 98. Figure 3.2-2 was developed using long-term continuous simulations for various combinations of bioretention areas collecting discharges from adjacent impervious surfaces. The simulations used the bioretention LID features in EPA SWMM5 to simulate the functioning of the bioretention system.

- In Figure 3.2-2, capture effectiveness is presented for various depths to the predevelopment SHWL. The SWMM5 LID feature does not account for water table elevation when considering the percolation rate from the planting media and nutrient-sorption layer to the underlying native soil. The model output was post-processed so that percolation was not allowed when the water table reached the bottom of the nutrient-sorption layer.

The average annual runoff load reduction is assumed to be equivalent to average annual percentage of runoff captured by the bioretention system.

Figure 3.2-2 Average Annual Runoff Capture Efficiency for a Bioretention System in City of Jacksonville



For the design curve, the bioretention storage is the surface ponding volume plus available storage in the planting media. The planting media available storage can be estimated as 15% of the planting media volume. Values shown in Figure 3.2.-2 assume that the surface ponding layer depth is maximized, subject to the SHWL and the minimum depth of the planting media. In the figure, depth to SHWL represents the distance from the bottom of the facility (i.e., bottom of planting media or optional nutrient-sorption layer) to the SHWL.

3.2.2.8 Maintenance Access

Access to the bioretention area must be provided at all times for inspection, maintenance, and landscaping upkeep. Sufficient space must exist around the bioretention system to allow accumulated surface sediments to be removed if the system fails infiltration tests or inspection.

3.2.2.9 Safety Features

Shallow bioretention systems generally do not require any special safety features. However, all Florida Department of Transportation and City of Jacksonville safety requirements must be met where applicable. 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. Roadway curbs and curb cuts may be considered as part of the design and should be consistent with the most recent FDOT Standard Specifications for Road and Bridge Construction.

3.2.2.10 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. Section 656.1210 (Landscaping requirements related to Comprehensive Plan policies) of the City of Jacksonville Ordinance Code requires that, if landscape planting is used to meet the preservation of native habitat vegetation requirement, at least 50% of these plantings shall consist of native vegetation that is suitable to the site. The following landscaping recommendations should be considered before storm flows are conveyed to the bioretention system:

- The pervious contributing area must be well vegetated to minimize erosion and sediment inputs to the bioretention system.
- Where feasible, a prefilter strip should be installed.
- If used, trees should be spaced appropriately depending on the type.
- If woody vegetation is used, it should be placed along the banks and edges of the bioretention system and not in the direct flow path.
- Only species well adapted to the regional climate must be used.
- Species planted in well-drained media with periodic surface ponding must be tolerant of short-term ponding as well as periods of low soil moisture.
- Vegetation must conform to regulations regarding line of sight.

3.2.3 Design Procedure

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

3.2.3.1 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 Sections 3.2.1.2 (Physical Constraints) and 3.2.2.2 (Location and Siting).
- *Step 2* – Determine the EIA for the tributary and the depth of storage over the EIA (inches). Mean annual runoff coefficients (C_{MA}), which are available in Table B-1, can be used to estimate the EIA for the average annual removal efficiency [EIA = C_{MA} x Drainage Area].
- *Step 3* – Compute the maximum retention volume that will be retained in the surface storage of the shallow bioretention system (less than 12 inches).
- *Step 4* – Set design elevations and dimensions of facility. See Section 3.2.2.3.
- *Step 5* – Design a pretreatment system if practicable, such as a prefilter strip.
- *Step 6* – Design the system to meet the recovery requirements in Section 3.2.2.5.

- *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 average annual 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 if applicable.

- *Step 10* – Prepare the vegetation and landscaping plan. A landscaping plan for the retention area should be prepared to indicate how the area will be established with vegetation. The plan should include irrigation details, particularly until the root system of the new vegetation has had time to be fully established.

3.2.3.2 Design Example

Assume that a stormwater BMP is needed to help meet the water quality objectives of a site and that sufficient peak-flow attenuation is provided downstream of the 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 SHWL is 36 inches below the surface. The following are sample calculations for evaluating the effectiveness of a proposed bioretention system:

- *Step 1* – Assume that the applicant has determined that the site meets the criteria specified in Section 3.2.1.2 and therefore a shallow bioretention system is an appropriate choice for a BMP on this site.

- *Step 2* – Determine the EIA for the tributary. Given that the contributing area is a 1-acre paved surface and 1-acre pervious surface with a CN of 78. The 1-acre paved surface can be considered DCIA. Therefore, based on Table B-1 using 50% DCIA and a non-DCIA (NDCIA) CN of 78, the mean annual runoff coefficient (C_{MA}) can be estimated to be 0.466. The EIA for 2 acres with C_{MA} of 0.466 acre is 0.932 acre [0.466 * 2]. Calculating EIA using the average annual runoff coefficient is specific to the bioretention practices as the annual effectives of bioretention systems was calculated based on an annual runoff coefficient.

- *Step 3* – Compute the maximum retention volume that will be retained in the surface storage of the shallow bioretention system. Given the site constraints, the area available for the shallow bioretention system is limited to approximately 80 feet by 30 feet (therefore, the area at top of storage = 80 * 30 = 2,400 sf). Applying the maximum surface ponding depth of 1 foot and assuming a side slope of 3:1 (area and bottom of storage = 74 * 24 = 1,776 sf), the maximum detention volume on the surface of the biofiltration area is calculated to be 2,088 cu ft [((2400 sf + 1776 sf)/2) * 1 foot)]. Assuming 12 inches of planting media and a vertical footprint of 1,776 sf, the storage in the planting media is estimated as 0.15 * 1,776 sf * 1 foot = 266 cubic feet. Total available storage is 2,088 + 266 = 2,354 cf, or 0.649 acre-inches.

- *Step 4* – Set the design elevations to meet the criteria specified in Section 3.2.2.3.

- *Step 5* – Assume that the applicant has found that sufficient space is available for a prefilter strip.

- *Step 6* – Run the appropriate recovery analysis under SHWL conditions and determines that the system can recover in 72 hours. This meets the criteria detailed in Section 3.2.2.5

- *Step 7* – If needed, design an emergency overflow and the appropriate erosion controls to meet the discharge from the 100-year/24-hour design storm event in the City of Jacksonville.

- *Step 8* – Calculate the average annual pollutant-removal efficiency. With a 12-inch ponding depth and 12-inch planting media, the bottom of the planting media is 24 inches from the ground surface, compared to the SHWL depth of 36 inches from the surface. Therefore, the depth to SHWL is 12 inches, and using Figure 3.2-2 is appropriate.

  Dividing the retention volume of 0.649 acre-in by the EIA of 0.932 acre results in a retention volume of 0.7 inch over the EIA. Figure 3.2-2 shows that a facility with depth to SHWL of 12 inches and volume/EIA value of 0.7 inches is expected to capture 40% of the average annual runoff, which would be retained and infiltrated by the shallow bioretention system.

  For comparison, if the depth to SHWL was 24 inches or greater, BMPTRAINS could have been applied to generate the runoff capture. In that case, the inches of retention over the 2-acre site would have been equal to 0.325 inch (0.649 acre-in divided by 2-ac site) and the runoff capture calculated by BMPTRAINS is 43%.

- *Step 9* – If needed, calculate the peak attenuation provided by the bioretention system. Two options are described in Section 3.2.2.6.

3.2.4 Operation and Maintenance

3.2.4.1 Inspection

The operation and maintenance entity is required to have the total surface water management system inspected by the appropriate Florida-registered and -licensed professional to ensure that the system is properly operated and maintained. The inspections must be consistent with ERP requirements regarding inspection of the stormwater system. If applicable the City of Jacksonville MS4 NPDES permit inspection and maintenance schedule for dry retention systems should also be followed (Appendix F). Inspection must be documented, and the documentation must be retained by the inspecting party for reference if necessary. At a minimum the following should be inspected:

- Inflow/outflow points for any clogging.
- Prefilter strip/grass channel and bioretention area for erosion or gullying.
- Trees and shrubs to evaluate their health.

3.2.4.2 Maintenance

System maintenance should include:

- Pruning, weeding and applying pre-emergent herbicide sparingly (if necessary) to keep any structures clear.
- Maintaining/mowing the prefilter or swale at least twice during the growing season and removing clippings from the flow path.
- Replacing mulch where needed when erosion is evident.
- Removing trash and debris as needed.
- If needed, replenishing mulch over the entire area every 2 to 3 years.

- Removing sediment from inflow system and outflow system as needed.
- Stabilizing any upstream erosion as needed.
- Removing and replacing any dead or severely damaged vegetation.

3.2.4.3 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. Failures and remedial actions should be reported to SJRWMD and City of Jacksonville. Formatting requirements and details on how reports should be submitted must be discussed and agreed to during the permitting process. For sites that include a large number of bioretention systems, a testing schedule in which a representative sample of bioretention systems is tested at the appropriate interval may be agreed to at the pre-application meeting or during the permitting process. Testing must include the following:

- The planting soils pH must be tested initially to establish that the soil pH is between 5.5 and 6.5. Testing should be done again if the vegetation is showing signs of stress. If soil pH is below 5.5, lime must be applied to raise the pH to 6.5.
- Bioretention systems require that a double-ring infiltration test be performed if the observed performance of the facility suggests diminished capacity for infiltration (e.g., ponded water is noted in the facility after more than 72 hours after rain). In that case, a double-ring infiltration test must be performed 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 3.2.2.5) or the average rate of the three tests is below the design criteria, the infiltration rate of the mulch layer and surficial planting media layer must be restored. Core aeration or cultivating of non-vegetated areas may be sufficient to restore the infiltration.

3.2.4.4 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 executed as a condition of plan approval.

3.2.5 References

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

3.3 Pervious Pavements

Key Considerations	**Practice Intent:** ▪ Promote rainfall infiltration/reduce stormwater runoff production while supporting traffic loading. **Design Criteria:** ▪ Must use an appropriately certified installer. ▪ Must use on a flat or minimal-slope area. ▪ Must incorporate a perimeter-edge restraint. ▪ Must use in-situ infiltration measurements. ▪ Typically includes a surface pavement overlaying a stone reservoir. **Advantage/Benefits:** ▪ Has potential to reduce the size of or eliminate stormwater structures from impervious areas. ▪ Increases usable/developable space or decreases developed footprint. ▪ May increase aesthetic value. **Disadvantages/Limitations:** ▪ May have increased maintenance requirements and costs. ▪ Not suitable for all site soil conditions. **Maintenance Requirements:** ▪ Vacuum the surface layer as needed when infiltration measurements are lower than 1.5 inches per hour for the pervious pavement layer.
Pollutant-Removal Potential	**M/H** **Total Suspended Solids** **M/H** **Nutrients**—Total Phosphorus/Total Nitrogen removal **M/H** **Metals**—Cadmium, Copper, Lead, and Zinc removal **M/H** **Pathogens**—Coliform, Streptococci, E.Coli removal
Stormwater Management Suitability	☒ **Water Quality** ☒ **Flood Attenuation**
Implementation Considerations	**Residential Subdivision Use:** Well suited **High-Density/Ultra-Urban:** Well suited **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

3.3.1 GENERAL

3.3.1.1 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, unlike 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 may be considered part of a treatment train, with credit based on available storage volume and the ability of the system to readily recover the storage volume.

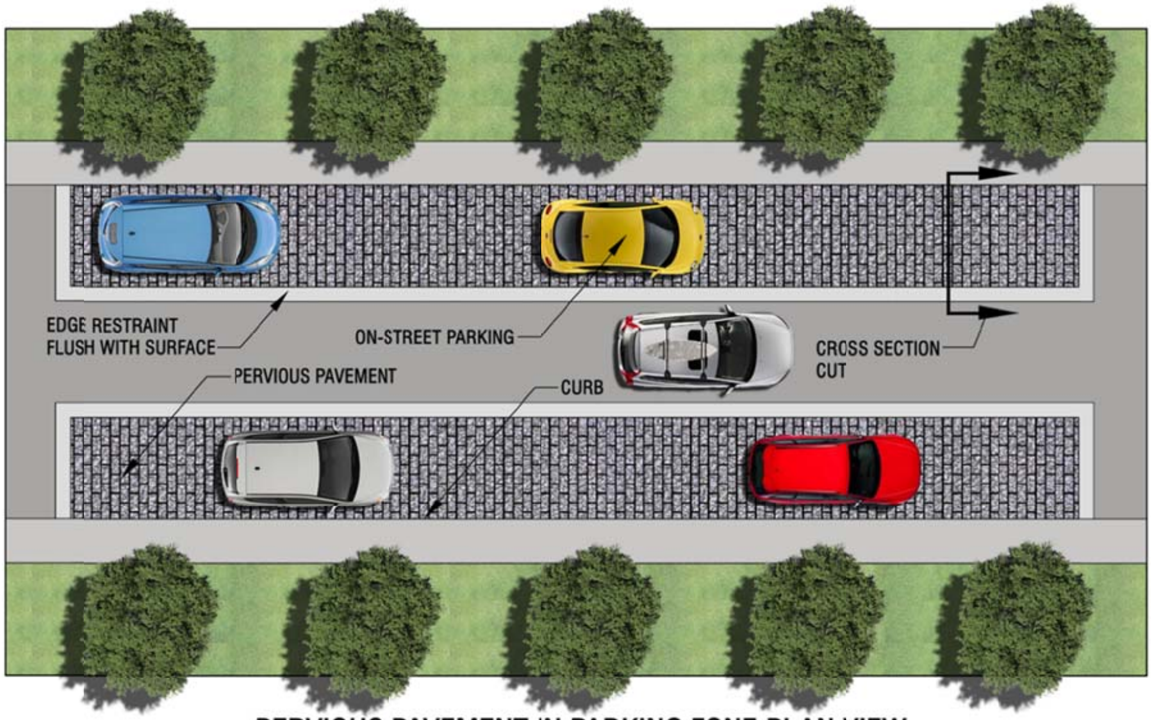
Many pervious pavement surface materials are available for different aesthetic considerations. Pervious pavements surface materials can be divided into two groups: modular pavers and cast-in-place pavements. Figure 3.3-1 shows common pervious pavement surface materials. Profiles of modular block pervious pavements systems typically include three layers: surface layer, filter layer, and reservoir layer. Cast-in-place systems can be incorporated into the three-layer design or a two-layer design (eliminating the filter layer) or designed as a single continuous layer of the surface material directly over the parent soil without a separate reservoir layer.

Figure 3.3-1 Common Pervious Pavement Materials: a) Permeable Interlocking Concrete Pavers, (b) Porous Concrete, (c) Flexi-pave™

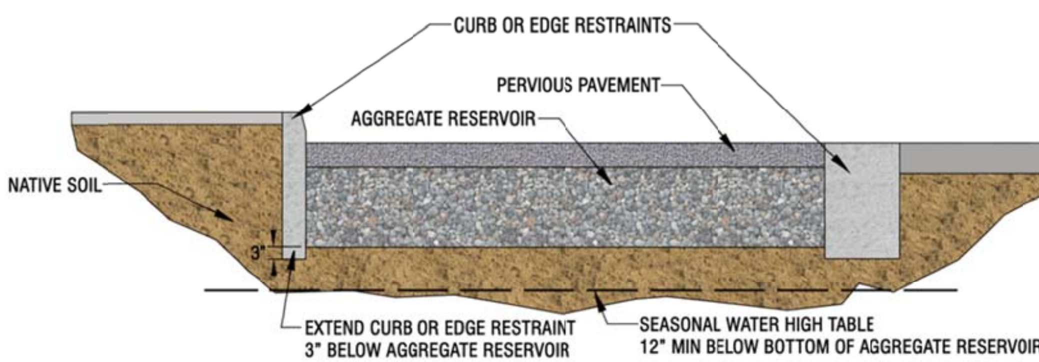
(a) (b) (c)

Figure 3.3-2 illustrates a typical single-layer profile system in which water is stored below the surface pavement within the aggregate material's pore space and then exfiltrates out of the profile into the native soil. A multi-layer profile including an upper filter layer and lower aggregate layer may also be used. Filter layers often consist of coarse sand or small aggregate (e.g., pea gravel), which helps stabilize the pavement surface.

Figure 3.3-2 Typical Pervious Pavement System



PERVIOUS PAVEMENT IN PARKING ZONE PLAN VIEW



CROSS SECTION OF PERVIOUS PAVEMENT IN PARKING ZONE

3.3.1.2 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 3.3-3).

Figure 3.3-3 Examples of Pervious Pavement (a: Driveway, b: Walking Path, c: Parking Lane)

(a) (b) (c)

Pervious pavements (such as modular pavers) can be designed to support heavier traffic loads. However, certain pervious pavement materials 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 runoff is infiltrated 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.

3.3.2 Design Considerations and Requirements

3.3.2.1 Structural Considerations and Requirements

This manual only provides requirements pertaining to the hydraulic functioning of pervious pavements. Therefore, the applicant should determine if the pervious pavement system is appropriate for the design's structural capability.

3.3.2.2 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

- The surface must be maintained to prevent significant clogging and improve infiltration rates. A pervious pavement system infiltration rate of at least 1.5 inches per hour is required in addition to exfiltration to the parent soil providing adequate drawdown shown in the recovery analysis. Tests must be conducted at least every 2 years and certified by an appropriate Florida-registered and -licensed professional.

- At least two (maximum of 10 for a site) infiltration 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 device that has been shown to be effective is the Embedded Ring Infiltrometer Kits (ERIKs) (Wanielista & Chopra, 2007).

- Sloping pervious pavement surfaces must be minimized. Parking lots and vehicular traffic areas with pervious pavement are recommended – but not mandated – 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.

- Parking lots and other vehicular traffic areas (excluding road rights-of-way, pedestrian walks, and bicycle paths) must be constructed to produce 2 inches of nuisance ponding over a portion of pavement near the infiltration testing site. *Nuisance ponding* is non-hazardous ponding designed to provide a visible warning that the pervious pavement system has failed and that remediation is required.

- 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

- For flood control, the pervious pavement system storage available after a 72-hour drawdown time can be used in the flood control calculation.

- Appropriate downstream flood attenuation must be provided if a pervious pavement system cannot provide sufficient runoff rate or volume reductions to meet its flood control requirements.

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

- The complete stormwater treatment system for the site must meet SJRWMD and City of Jacksonville water-quantity discharge requirements.

Recovery Requirements

- The SHWL must be at least 12 inches below the bottom of the pervious pavement system profile.

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

- The storage volume used to determine the CN or Rational C calculation (for flood-control credit) must be recovered within 72 hours under SHWL conditions.

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

- A safety factor of 2.0 or more must be applied to the recovery analysis to allow for geological uncertainties.

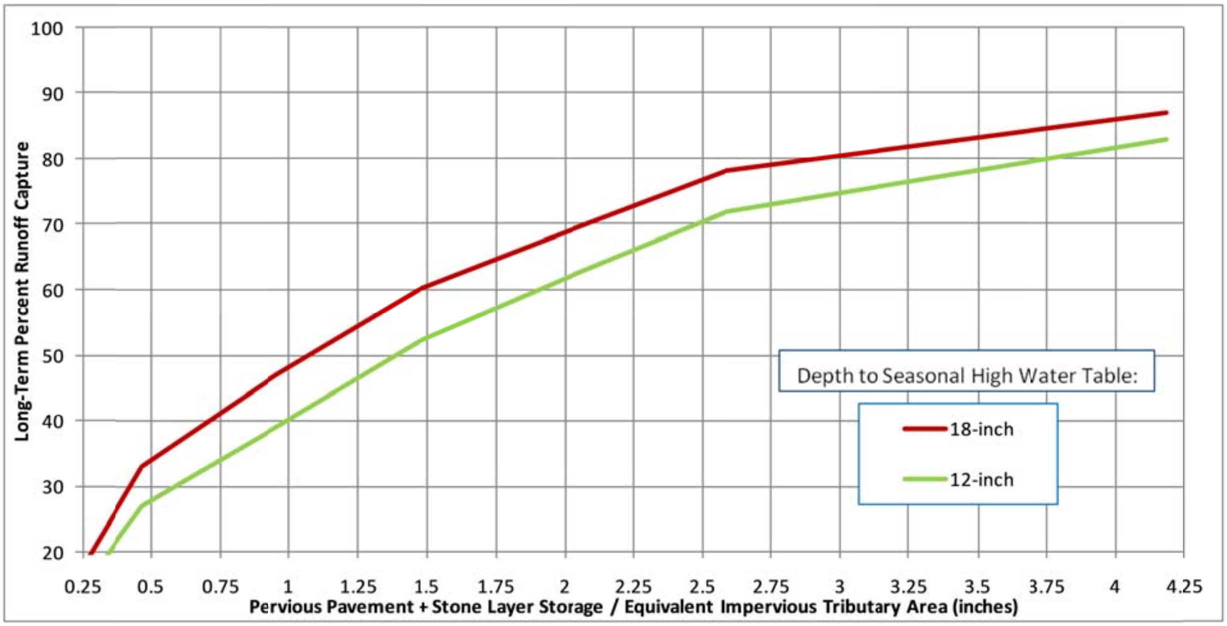
3.3.2.3 Water Quality Treatment Requirements/Credits

- Designs will be assumed to achieve annual mass removal efficiency consistent with the dry retention depths found in Appendix D if the pervious pavement system 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 = 98.

- Alternatively, continuous simulation or a design curve (see Figure 3.3-4) can be used to evaluate the percent runoff capture. Figure 3.3-4 was developed using EPA SWMM5 based on long-term continuous simulations for various combinations of pervious pavement system storage that also is collecting discharges from adjacent traditional impervious areas, such as impervious pavement or roof tops, using the pervious pavement LID feature in SWMM5. Values are plotted based on the ratio of pervious pavement system storage (pavement plus aggregate) to the EIA for the contributing area. Thus, the EIA of the total watershed adding runoff to the pavement (including the pervious pavement area) must be calculated.

- In Figure 3.3-4, capture effectiveness is presented for depths to predevelopment SHWL that are less than 24 inches from the bottom of the pervious pavement system. The SWMM5 LID feature does not account for water table elevation when considering the percolation rate from the pervious pavement system to the underlying native soil. The model output was post-processed so that percolation was not allowed when the water table reached the bottom of the stone reservoir below the pervious pavement.

Figure 3.3-4 Long-Term Runoff Capture Based on Depth to Pre-Development Seasonal High Water Level and Pervious Pavement System Storage



3.3.2.4 Maintenance Requirements

- 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.).

- If the pervious pavement system infiltration rates measured using the installed testing device 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.

3.3.2.5 Safety Considerations

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

- 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.

3.3.2.6 Additional Design Considerations

- 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 3 inches below the bottom of the reservoir material.

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

- Runoff from nearby roofs or adjacent impervious areas may be routed onto the pervious pavement. However, this may require more frequent testing of the infiltration capacity of the pervious pavement system due to the increased risk of overloading the pervious pavement with sediment.

3.3.3 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. Applicants 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 the City of Jacksonville. Applicants should consult with appropriate City and State agencies for any variations or additions to these criteria.

3.3.3.1 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. Usually the system will be designed to meet either a desired annual pollutant load removal to be consistent with the "net improvements standards" of impaired waters or the removal efficiency of a design will need to be calculated.

  If the annual pollutant load removal is the desired approach, the designer must know the meteorological zone, the mean annual rainfall, the predeveloped and postdeveloped land use, and the typical site hydrologic characteristics. This information is used to determine the annual mass loading for nitrogen and phosphorus for both the predeveloped and postdeveloped conditions. The required treatment efficiency may be calculated to meet the "net improvement" criteria. The event mean concentration (EMC) for general land use categories in Florida is in Appendix D. Load reductions should be calculated using SJRWMD-accepted data for EMCs and load reductions.

If the site is not located in an impaired water body, the required water quality annual pollutant load removal efficiency is 80%.

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

  The variables that depend on the design and are needed to calculate the efficiency of the pervious pavement system are the postdeveloped DCIA, the postdeveloped Non-DCIA (NDCIA) CN, the area of pervious pavement, and the storage in the pavement system. To optimize the system and meet the required removal efficiency determined in Step 1, the designer may need to 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 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 SHWL?

- *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 Appendix D.

- *Step 4* – Verify storage recovery time.

  A recovery analysis is needed to demonstrate that the pervious pavement system meets the requirements listed in Section 3.3.2.2 (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 72 hours of recovery can be accounted for in the flood protection/attenuation calculations. This storage volume can be evaluated by one of two methods:

  - The available pervious pavement storage can be evaluated as “soil storage” when calculating the weighted CN for the site.
  - The pervious pavement area can be included in the DCIA calculations and the storage can be evaluated as “pond storage.”

3.3.3.2 Design Emergency Overflow

A pervious pavement system may overflow during extreme rainfall or if a pervious pavement fails. An adequately sized emergency overflow must be sized to convey runoff from the pervious pavement system that could occur from the design storm.

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

3.3.3.3 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. The design problem can also be solved using the BMPTRAINS model (http://www.stormwater.ucf.edu/). However, the user is encouraged to understand the input data and the process for solving for the capture volume (average annual efficiency).

Problem Statement

The example includes 2 acres of roadway and parking lane that will be a combination of pervious pavement and traditional pavement. By design, the traditional pavement runoff is routed to the pervious pavement. The site was previously Upland Scrubby Flatwoods on soils corresponding with the Hydrologic Soil Group B/D. The SHWL in this location is approximately 24 inches below the surface. The site is in the Meteorological Zone 4 and has a mean annual rainfall of 52 inches. The predeveloped curve number for the pervious area (CN) is 78.

- *Step 1* – Determine the required/desired removal efficiency.

  We assumed that the site is located in an impaired water body; therefore, the design intent will be to demonstrate a "net improvement." Using BMPTRAINS, the mean TN and TP (mg/L) concentrations can be determined for the site predevelopment and postdevelopment land uses:

  - Pre: Upland Mixed – Total N = 1.023 mg/L and Total P = 0.027 mg/L
  - Post: Highway – Total N = 1.64 mg/L and Total P = 0.22 mg/L

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

  We assumed that 50% of the site will be pervious pavement and that the site requires minimal fill; therefore, the bottom of the proposed pavement will be assumed to be at the existing grade. Since the SHWL is 24 inches below the existing grade and a 12-inch separation must be maintained between the SHWL and the bottom of the pervious pavement system, 12 inches are available to be used for the pervious pavement reservoir. Given a 4-inch-thick pervious concrete (void space 25%) and a 12-inch-thick #57 stone pavement reservoir (sustainable void space 21%), the inches of pavement storage (S) can be calculated.

  S = (4" * 0.25) + (12" * 0.21) = 3.5"

  The predeveloped annual runoff coefficient, annual runoff, and annual mass load can also be calculated.

  The predeveloped annual runoff coefficient (C) interpolated from Table B-1 (or calculated in BMPTRAINS) given a CN of 78 and a DCIA of 0%. C = 0.116

  The annual runoff (AR in ac-ft/year) = annual rainfall (in/yr) * area (ac) * C * (1 ft/12 in)

  AR = 52 * 2 * 0.116 / 12 = 1.01 ac-ft/yr

  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).

  $AML_{N\text{-}pre}$ = 1.01 * 43560 * 7.48 * 3.785 * 1.023 / 10^6 = 1.27 kg/year

$AML_{P\text{-}pre}$ = 1.01 * 43560 * 7.48 * 3.785 * 0.027 / 10^6 = 0.04 kg/year

- *Step 3* – Continuing defining the inputs and performing the calculations.

  The impervious pavement and pervious pavement that make up the 2-acre roadway and parking lane system should be treated as DCIA to determine how much runoff enters the pervious pavement system.

  From Table B-1 – the post C, given DCIA of 100% = 0.823

  The post AR = 52 * 2 * 0.823 / 12 = 7.13 ac. ft / year

  $AML_{N\text{-}post}$ = 7.13 * 43560 * 7.48 * 3.785 * 1.64 / 10^6 = 14.42 kg/year

  $AML_{P\text{-}post}$ = 7.13 * 43560 * 7.48 * 3.785 * 0.22 / 10^6 = 1.93 kg/year

  The required removal efficiency to meet the net improvement is determined from the AMLs calculated for nitrogen in this example.

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

  E% = (1 – (1.27/ 14.42)) * 100 = 91.2%

  The required retention depth can then be determined using Appendix D given CN = 98 and DCIA = 100%.

  Based on Appendix D, the mass removal efficiency is 92.3% for a retention depth of 2.75 inches.

  The corresponding required treatment storage = area * retention depth * 43,560 / 12 = 19,965cf.

  The provided pervious pavement storage = pervious pavement area * inches of pavement storage S * 43,560/12

  Since 50% was used for the impervious area, the system of roadway and parking lane is 50% pervious pavement and the pervious pavement area is 2 ac * .5 = 1.0 ac.

  Provided storage = 1.0 acre * 3.5 inches * 43,560 /12 = 12,705 cf

  The provided storage is less than the required storage, and the system would not meet the net improvement requirement.

  The calculations in BMPTRAINS are based on the presumption of a 24-inch separation between the bottom of the stone reservoir and the SHWL. In this case, the separation was only 12 inches, and therefore the curves in Figure 3.3-4 should be used. The EIA for the site is the total site area (2 acres) times the calculated post development runoff coefficient C of 0.823, or 1.646 acres. The storage of the pervious pavement system is the area of pavement (1 acre) times the depth of storage (3.5 inches), or 3.5 acre-inches. The ratio is therefore 3.5/1.646 = 2.13 inches. Based on the ratio of 2.13 and the 12-inch depth to the predevelopment SHWL, the expected runoff capture is 63%, which is less than the required 93% storage. Refinement of the design and/or additional water quality treatment will be required.

- *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 3.3.2.2 (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 72 hours of recovery can be accounted for in the flood protection/attenuation calculations. This storage volume can be evaluated by one of two methods:

  - The available pervious pavement storage can be evaluated as “soil storage” when calculating the weighted CN for the site.

  - The pervious pavement area can be included in the DCIA calculations and the storage can be evaluated as “pond storage.”

The design calculations indicate that the design would meet the net improvement goal if the depth to SHWL is 24 inches or more. However, because the depth to SHWL is only 12 inches, the design will not fully meet the requirement but will provide substantial benefit. The remaining water quality treatment may be provided by a downstream BMP (e.g., detention facility designed to meet peak-shaving requirements for extreme storms).

3.3.4 Construction

3.3.4.1 Soil Excavation

- 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 on the parent soil. The maximum allowable soils compaction is 95% Modified Proctor Density (ASTM D1557) to a minimum depth of 24 inches.

- 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.

3.3.4.2 Aggregate Installation

- Aggregate for the reservoir layer must be washed rock such as No. 4 or 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.

- 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.

3.3.4.3 Pavement Installation

The pervious pavement must be installed by a contractor certified by the pervious pavement product manufacturer or association to install the pervious pavement specified. For example pervious concrete systems must be installed by a contractor that is certified by the National Ready Mixed Concrete

Association as being a pervious concrete craftsman. Certification should be verified on either the manufacture's or association's website.

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.

3.3.5 OPERATION AND MAINTENANCE

3.3.5.1 Inspection

The operation and maintenance entity is required to have the total surface water management system inspected by an appropriate Florida-registered and -licensed professional to ensure that the system is properly operated and maintained. The inspections shall be performed 1 year after operation is authorized by both the City and SJRWMD and every 2 years thereafter. Inspection must be documented, and the documentation must be retained by the inspecting party for reference if necessary. At a minimum the following should be inspected:

- The surface for any compromised sections of the pavement. Compromised sections should be repaired as needed, whether fractured, shifted, or otherwise damaged.
- The surface for the accumulation of sediments and other clogging material.
- Voids for missing aggregate. Missing aggregate should be added to the pavement surface as needed.

3.3.5.2 Testing

The rate of clogging material accumulating will vary based on location and traffic. Surface infiltration rates must be tested at least every 2 years to ensure that rates are not limiting the performance of the system. The frequency of the required testing may be increased in instances where runoff from adjacent impervious areas is directed onto the pervious pavement. If the pervious pavement system infiltration rates are less than 1.5 inches per hour, maintenance must be performed for the respective areas. Maintenance such as vacuuming should typically be carried out over the entire pervious pavement and should not be limited to the areas where the infiltration rate has failed.

3.3.5.3 Maintenance

Excessive direct rainfall and discharge from adjacent tributary areas can overwhelm a pervious pavement system by intensity (limited by surface infiltration rate) or depth (limited by storage volume). Ponding due to rainfall and intensity of flows onto the pavement exceeding the surface infiltration rate should begin to be alleviated once the combined flows 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 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 difficult to extract, thus permanently reducing infiltration rates. Alternative methods (e.g., 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 the pervious pavement system 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 in the pervious pavement system are required. Any surface shifting or cracking should be promptly repaired. Filter material removed during vacuum sweeping for modular systems should be replenished with material that meets the specifications of the original filter material.

3.3.5.4 Additional Maintenance Considerations and Requirements

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

3.3.6 References

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

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

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

Appendix A

LID Site-Planning and Evaluation Guidance Chart

LOW IMPACT DEVELOPMENT PLANNING CONSIDERATIONS	PROJECT APPLICABILITY (Y or N)	LOW IMPACT DEVELOPMENT ALTERNATIVES AVAILABLE TO MEET STORMWATER MANAGEMENT SITE NEEDS IN DUVAL COUNTY						
		CONVEYANCE SWALES (SEE SECTION 3.1)	SHALLOW BIORETENTION (SEE SECTION 3.2)	PERVIOUS PAVEMENTS (CHAPTER 3.3)	GREENROOF TREATMENT (SEE SARASOTA COUNTY LID MANUAL)	RAINWATER HARVESTING (SEE SARASOTA COUNTY LID MANUAL)	VEGETATIVE FILTER STRIPS (SEE SARASOTA COUNTY LID MANUAL)	CONFINED URBAN VEGETATIVE SYSTEMS (SEE SARASOTA COUNTY LID MANUAL)
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 DEVELOPEMENT (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 SPEICIAL 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.		●	●	●	●	●	●	●

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	○

* While wetlands both naturally benefit and provide benefits to the environment from stormwater via sheetflow, any new direct "conveyance" to wetlands or an existing conveyance that has its discharges significantly altered might be considered a regulatory event if that wetlands is considered to be waters of the State or US. Additionally, a direct new conveyance, such as a swale, could have deleterious effects on the wetlands resource. The applicant should check with the regulatory authorities before proceeding with site plans.

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 Duval County and SJRWMD permitting requirements for stormwater management.

Appendix B

Rainfall and Runoff Data

Figure B-1 Average Annual Rainfall Data for Duval County and Vicinity

(Source Florida Department of Environmental Protection and Water Management Districts Environmental Resource Permit Stormwater Quality Applicant's Handbook – March 2010 – Draft)

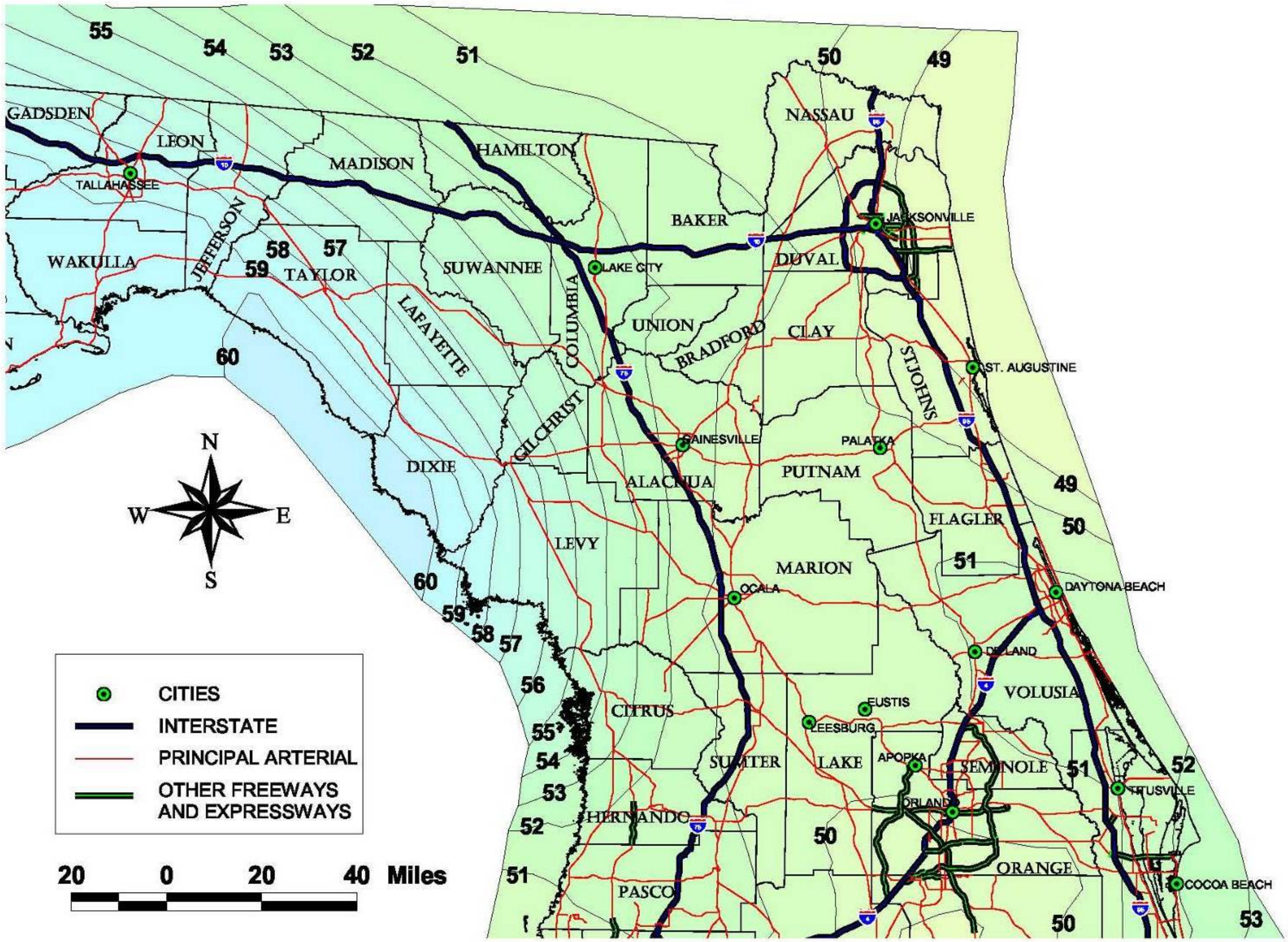


Table B-1 Mean Annual Runoff Coefficient as a Function of DCIA and Pervious CN

(Source Florida Department of Environmental Protection and Water Management Districts Environmental Resource Permit Stormwater Quality Applicant's Handbook – March 2010 – Draft)

Zone 4

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

NDCIA CN	Percent DCIA																				
	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

Appendix C

Grassed Conveyance Swale Design Information

Table C-1 Maximum Permissible Velocity for Grassed Conveyance Swales
(Source Livingstone et al 1988)

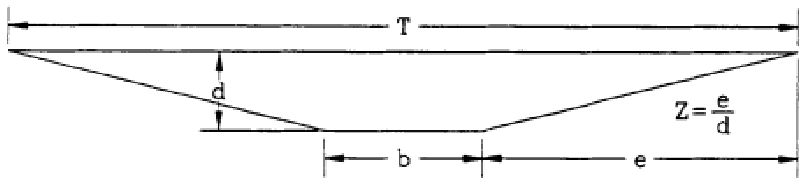
Channel Slope	Lining	Permissible Velocity (ft/sec)
0 – 5%	Bermuda grass	6.0
	Bahia	5.0
	Bluestem (broomsedges)	5.0
	Grass-legume mixture	4.0
	Sericea lespedeza	2.5
	Annual lespedeza	2.5
	Small grains (temporary)	2.5
5 – 10%	Bermuda grass	5.0
	Bahia	4.0
	Bluestem (broomsedges)	4.0
	Grass-legume mixture	4.0

Table C-2 Classification of Vegetation Cover as to Degree of Retardance
(Source Livingston et al 1988)

Retardance Class	Cover	Condition
A	Bluestem (broomsedges)	Excellent stand, tall (average 36")
B	Bermuda or Bahia	Good stand, tall (average 12")
	Native Grass mixture (bluestem, vasey grass, and other long and short wet prairie grasses)	Good stand, unmowed
	Lespedeza sericea	Good stand, not woody tall (average 19')
C	Bahia	Good stand, uncut (6-8")
	Bermuda grass	Good stand, mowed (average 6")
	Centipede grass or St. Augustine	Very dense (average 6")
D	Bermuda or Bahia	Good stand, cut to 2.5" height Cut to 2" height
	Lespedeza sericea	Very good stand before cutting
E	Centipede grass or St. Augustine	Good stand, cut to 1.5" height

Figure C-1 Typical Waterway Shapes and Mathematical Expressions for Calculating Cross-sectional Area, Top Width, Hydraulic Radius, and Wetted Perimeter
(Source Livingston et al 1988)

Trapezoidal Shape



Cross-Sectional Area (A) = $Zd^2 + bd$

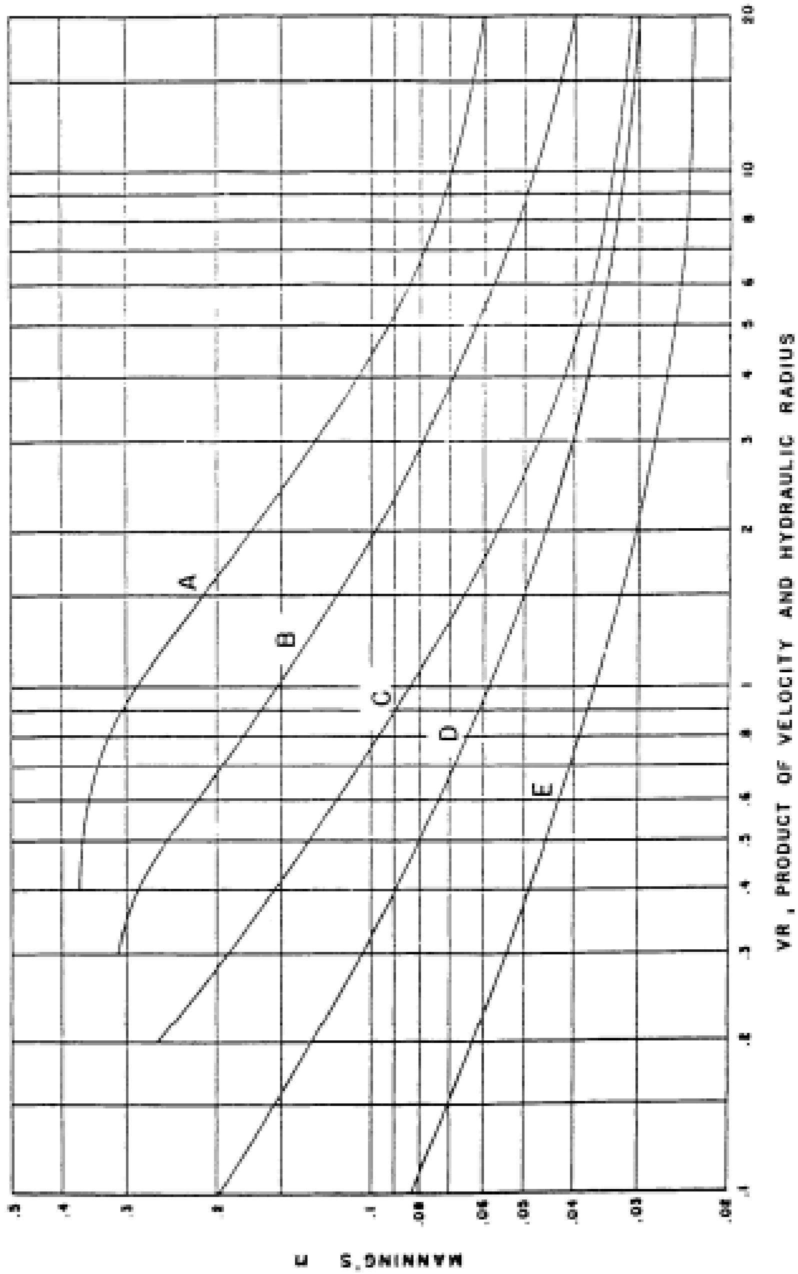
Top Width (T) = $b + 2dZ$

Hydraulic Radius = $\dfrac{Zd^2 + bd}{b + 2d\sqrt{Z^2 + 1}}$

Wetted Perimeter (P) = $b + 2d\sqrt{Z^2 + 1}$

Figure 30-2. Typical Waterway Shapes and Mathematical Expressions for Calculating Cross-sectional Area, Top Width, Hydraulic Radius and Wetted Perimeter
Source: Livingston et al. 1988

Figure C-2 **Manning's "n" Related to Velocity, Hydraulic Radius, and Vegetal Retardance**
(Source Livingston et al, 1988)



Appendix D

Mean Annual Mass Removal Efficiencies for Various Retention Depths in Zone 4

Table D Mean Annual Mass Removal Efficiencies for Zone 4

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

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

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

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	97.40	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

Appendix E

Event Mean Concentrations

Table E Event Mean Concentrations / Runoff Characteristics
(Source "Draft Best Management Practice Analysis Aid" from *University of Central Florida, Stormwater Management Academy*)

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

Appendix F

City of Jacksonville NPDES Permit Inspection and Maintenance Schedule for Structural Controls and Roadways

TABLE II.A.1.a INSPECTION AND MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS AND ROADWAYS (NPDES FLS000012-003)

STRUCTURAL CONTROLS (1)

Notes:
(1) The **structural controls listed herein are not intended to be a complete listing of all stormwater structures owned and operated by the permittee. The permittee is responsible to perform and record inspections and maintenance of all structures** that **comprise its municipal separate storm sewer system.**
(2) The inspection and maintenance activities in the third and fifth columns of this table are not intended to address every possible inspection need or maintenance activity that may be required to assure that an existing structural control continues to function properly or as permitted.
(3) **Excessive petroleum hydrocarbon contamination** can present severe sediment disposal / cleanup problems. **Evidence of such pollution includes very dark oily stains, particularly at inlet and outlet structures and strong odors of gasoline, etc. The source of such pollutant discharges to the MS4 should be determined and removed if possible. Otherwise, pretreatment practices should be used as necessary to insure that stormwater runoff is not contaminated beyond levels normally observed in runoff from highways and parking lots.**
(4) Use only pesticides approved by USEPA and FDACS for aquatic sites to control weed pests in and around treatment facilities. Use of pesticides and chemicals for the control of invasive species and common undesirable aquatic plants should be minimized. Careful herbicide selection and application is essential to minimize harm to desirable plants and animals.
(5) **Solids disposal. Stormwater system sediments including street sweepings, catch basin sediments, collected screenings, slurry, sludge, and other solids shall be handled and disposed of pursuant to Department rules and guidance,** which is available at: www.dep.state.fl.us/waste/quick_topics/publications/shw/solid_waste/GuidanceForSt-Sweep050304Final.pdf.

Dry Retention Systems

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every three years**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect the system for storage volume recovery within the permitted time, generally less than 72 hours. Dead or dying grass on the bottom and / or standing water following three or more days of dry weather is an indication of potential clogging and reduced infiltration capacity. • Inspect and monitor sediment accumulation on the bottom or inflow / outflow to prevent loss of storage volume, clogging of the system or the inflow / outflow pipes. • Inspect vegetation of bottom and side slopes to assure it is healthy, maintaining coverage, and that no erosion is occurring within the system. • Inspect inflow and outflow structures, trash racks, and other components for signs of undercutting or piping, settling, or damage, and for accumulation of debris and trash that would cause clogging and adversely impact operation of the system. • Inspect the system for potential mosquito breeding areas such as where standing water occurs after 72 hours or where cattails or other invasive vegetation becomes established. • Note any signs of excessive petroleum hydrocarbon contamination and handle appropriately (3).			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• If needed, restore the infiltration capacity of the system by scraping, discing or otherwise aerating the bottom so that it meets the permitted recovery time for the required treatment volume. • Remove accumulated sediment from the bottom and inflow and outflow pipes and dispose of properly. If possible, sediment removal should be done when the system is dry and when the sediments are cracking. • Maintain healthy vegetative cover to prevent erosion in the bottom, side slopes or around inflow and outflow structures (4). Vegetation roots also help to maintain soil permeability. Mow as needed. • Conduct repairs to prevent undercutting or piping. Remove trash and debris from inflow and outflow structures, trash racks, and other system components to prevent clogging or impeding flow. • Eliminate mosquito breeding habitats.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Dry Detention Systems

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every three years**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect the system for storage volume recovery within the permitted time, generally less than 72 hours. Dead or dying grass on the bottom and / or standing water following three or more days of dry weather is an indication of potential clogging and reduced infiltration capacity. • Inspect and monitor sediment accumulation on the bottom and at the inflow / outflow to prevent loss of storage volume, clogging of the system or the inflow / outfall pipes. • Inspect vegetation of bottom and side slopes to assure it is healthy and maintaining coverage, no erosion is occurring, and excessive seepage that may indicate excessive ground water inflow is not occurring. • Inspect inflow and outflow structures, trash racks, and other system components for signs of undercutting, piping, settling, or damage, and for accumulation of debris and trash that would cause clogging and adversely impact proper operation. • Inspect the system for potential mosquito breeding areas such as where standing water occurs after 72 hours or where cattails or other invasive vegetation becomes established. • Note any signs of excessive petroleum hydrocarbon contamination and handle appropriately (3).			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• If needed, restore the infiltration capacity of the system by scraping, discing or otherwise aerating the bottom so that it meets the permitted recovery time for the required treatment volume. • Remove accumulated sediment from the system and inflow / outflow pipes and dispose of properly (3, 5). If possible, sediment removal should be done when the system is dry and when the sediments are cracking. • Maintain healthy vegetative cover to prevent erosion in the bottom, side slopes or around inflow and outflow structures (4). Mow as needed. Monitor seepage and repair if needed. • Conduct repairs to prevent undercutting, piping, or damage. Remove trash and debris from inflow and outflow structures, trash racks, and other system components to prevent clogging or impeding flow. • Eliminate mosquito breeding habitats.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Wet Detention Systems

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every three years**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect the system for storage volume recovery within the permitted time frame. • Inspect the system for excessive sediment accumulations that cause a 20% or more decrease in the wet detention system's permitted storage volume. • Inspect inflow and outflow structures, trash racks, and other system components for signs of undercutting, piping, settling, or damage, and for accumulation of debris and trash that would cause clogging and adversely impact proper operation. • Inspect vegetation on side slopes to assure it is healthy and maintaining coverage, and that no erosion is occurring. • Inspect the wet detention system and, if applicable, littoral zone to assure that cattails or other invasive vegetation are not becoming established.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• If required, take actions to assure that storage volume is recovered within the permitted time frame. • Remove accumulated sediments to restore permitted storage volume and dispose of properly (3, 5). • Conduct repairs to prevent undercutting, piping, or damage. Remove trash and debris from inflow and outflow structures, trash racks, and other system components to prevent clogging or impeding flow. • Maintain healthy vegetative cover to prevent erosion of side slopes or around inflow and outflow structures (4). Remove any trees or shrubs that may have become established on the discharge structure embankment, if applicable. • Remove cattails and other exotic vegetation from the littoral zone, if applicable, and replant appropriate vegetation if needed to meet littoral zone requirements (4).			POSSIBLE MAINTENANCE ACTIVITIES (2)

Underdrain Filter Systems

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every 18 months**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION

POSSIBLE INSPECTION ACTIVITIES

• Inspect the system for storage volume recovery within the permitted time, generally less than 36 hours. Dead or dying grass on the bottom and / or standing water following three or more days of dry weather is an indication of potential clogging and reduced infiltration or filtration capacity. Inspect filter system outflow to assure it is operating as designed and is not clogged.
• Inspect and monitor sediment accumulation on the bottom or inflow / outflow to prevent loss of storage volume, clogging of the system or the inflow / outflow pipes.
• Inspect vegetation of bottom and side slopes to assure it is healthy, maintaining coverage, and that no erosion is occurring within the system.
• Inspect inflow and outflow structures, trash racks, and other components for signs of undercutting or piping, settling, or damage, and for accumulation of debris and trash that would cause clogging and adversely impact operation of the system.
• Inspect the system for potential mosquito breeding areas such as where standing water occurs after 72 hours or where cattails or other invasive vegetation becomes established.

FREQUENCY of MAINTENANCE: **As needed based on inspection to assure proper operation**

POSSIBLE MAINTENANCE ACTIVITIES (2)

• If needed, restore the infiltration or filtration capacity of the system by scraping, discing or otherwise aerating the bottom and / or by conducting appropriate maintenance of the filter system so that it meets the permitted recovery time for the required treatment volume.
• Remove accumulated sediment from the bottom and inflow and outflow pipes and dispose of properly. If possible, sediment removal should be done when the system is dry and when the sediments are cracking.
• Maintain healthy vegetative cover to prevent erosion in the bottom, side slopes or around inflow and outflow structures (4). Vegetation roots also help to maintain soil permeability. Mow as needed.
• Conduct repairs to prevent undercutting or piping. Remove trash and debris from inflow and outflow structures, trash racks, and other system components to prevent clogging or impeding flow.
• Eliminate mosquito breeding habitats.

Exfiltration Trench / French Drains

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every three years**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION

POSSIBLE INSPECTION ACTIVITIES

• Inspect facility for sediment accumulation in the pipe (when used) and for storage volume recovery (i.e., drawdown capacity). If present, observation wells and inspection ports should be checked following 3 days minimum dry weather. Failure to percolate stored runoff to the design treatment volume level within 72 hours indicates binding of soil in the trench walls and / or clogging of geotextile wrap with fine solids.
• Inspect appurtenances such as sedimentation and oil and grit separation traps or catch basins as well as diversion devices and overflow weirs when used. Diversion facilities and overflow weirs should be free of debris and ready for service. Sedimentation and oil / grit separators should be scheduled for cleaning when sediment depth approaches cleanout level. Cleanout levels should be established not less than 1 foot below the invert elevation of the chamber.

FREQUENCY of MAINTENANCE: **As needed based on inspection to assure proper operation**

POSSIBLE MAINTENANCE ACTIVITIES (2)

• Conduct minor maintenance measures to restore infiltration rates to acceptable levels. This may include removal of accumulated sediments by mechanical or manual means.
• Major maintenance (total rehabilitation) is required to remove accumulated sediment in most cases or to restore recovery rate when minor measures are no longer effective or cannot be performed due to design configuration.
• Remove trash and debris from diversion facilities and overflow weirs. Clean out sedimentation and oil / grit separators when sediment depth approaches cleanout level and dispose of properly (3, 5).
• Remove debris from the outfall or "smart box" (diversion device in the case of off-line facilities).

Grass Treatment Swales (Dry)

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Once every three years**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect the swale for storage volume recovery within the permitted time, generally less than 72 hours. Dead or dying grass, cattails / aquatic vegetation in the swale and / or standing water following three or more days of dry weather is an indication of potential clogging and reduced infiltration capacity. • Inspect the swales for debris or litter accumulation or damage to structures including diversion devices, inflow pipes, driveway culverts, and swale blocks. • Inspect and monitor sediment accumulation in the swale or at inflows to prevent clogging of the swale or the inflow pipes. • Inspect vegetation of bottom and side slopes to assure it is healthy, maintaining coverage, and that no erosion is occurring within the swale. • Inspect the swale for potential mosquito breeding areas such as where standing water occurs after 72 hours or where cattails or other invasive vegetation becomes established. • Inspect the swale to determine if parking, filling, excavation, construction of fences, or other objects are damaging or obstructing stormwater flow in the swales.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• If needed, restore the infiltration capacity of the swale system by scraping, discing or otherwise aerating the bottom so that it meets the permitted recovery time for the required treatment volume. • Remove trash and debris, especially from inflow or outflow structures, to prevent clogging or impeding flow. Repair any damages to structures within the swale system as needed to maintain proper operation. • Remove accumulated sediment from the swale and inflow or outflows and dispose of properly (3, 5). If possible, sediment removal should be done when the swale is dry and when the sediments are cracking. • Maintain healthy vegetative cover to prevent erosion of the swale bottom or side slopes (4). Mow grass as needed. • Eliminate mosquito breeding habitats. • Repair any damage to the swale system and remove fences or other obstructions that may have been built in the swale system.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Stormwater Pump Stations

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Semi-annually and more frequently as needed	**Semi-annually and more frequently as needed**	**Frequently as needed**	FREQUENCY of INSPECTION
• Inspect pump for proper operation. • Inspect inlets, bar screens (if used) and other associated components for debris or litter to assure that pump operates properly.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Maintain or repair pump as needed to assure proper operations. • Remove debris, litter, and sediments as needed to assure proper operations. Properly dispose of the litter and debris collected. Properly dispose of sediment collected (3, 5).			POSSIBLE MAINTENANCE ACTIVITIES (2)

Pollution Control Boxes (e.g., baffle boxes, CDS units, hydrodynamic separators, catch basin inserts, etc.)

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Quarterly, unless historic clean out operation records demonstrate that a more or less frequent schedule is appropriate	**Quarterly, unless historic clean out operation records demonstrate that a more or less frequent schedule is appropriate**	**Until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect inlets, outlets, and other system components for damage that would prevent proper flow conditions and operation. • Inspect and monitor sediment accumulation in the pollution control box and at the inflow / outflow to prevent loss of storage volume, clogging of the inflow / outfall pipes. • If applicable, inspect and monitor vegetation and debris accumulation in the pollution control box screens to prevent loss of storage volume or clogging of the system. • If applicable, inspect absorbent materials used to trap hydrocarbons or bacteria to determine if they need replacement.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Repair any damage to assure proper flow conditions and operation. • Remove accumulated sediment and dispose of properly. • Remove accumulated vegetation and debris and dispose of properly (3, 5). • Replace absorbent materials as required for proper operation. • Follow all manufacture's recommended maintenance schedule and activities.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Major Stormwater Outfalls

New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Annually the first two years of operation	**Annually unless historic operation records demonstrate that a more or less frequent schedule is appropriate**	**Annually until the chronic problems are corrected**	FREQUENCY of INSPECTION
• Inspect outfalls to assure they are not clogged with litter, debris, or sediment and they are flowing properly. • Inspect for damaged headwalls, seepage around pipe, erosion of bank around outfall, erosion or sedimentation at outfall discharge point, and damage or clogged riprap.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Remove debris, litter, and sediments as needed to assure proper operations. Properly dispose of the litter and debris collected. Properly dispose of sediment collected (3, 5). • Repair any structural damage to assure proper operation. • Maintain healthy vegetative cover to prevent erosion of banks or areas near outfalls (4). • Assure that discharges from outfalls are not causing erosion and sedimentation.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Weirs or Other Control Structures Associated with Stormwater Structural Controls

New systems (i.e., those in operation after the effective date of the permit)	Existing systems without chronic problems	Existing systems with chronic problems that affect the permitted operation of the system	
Same as specified in this column for the type of stormwater control with which it is associated	**Same as specified in this column for the type of stormwater control with which it is associated**	**Same as specified in this column for the type of stormwater control with which it is associated**	FREQUENCY of INSPECTION
• Inspect weirs / control structures for damage that would prevent proper flow conditions and operation. • Inspect and monitor sediment accumulation behind weirs / control structures to prevent loss of storage volume and adverse impacts on flow and operation. • Inspect and monitor litter / debris accumulation behind weirs / control structures to prevent loss of storage volume and adverse impacts on flow and operation.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Repair any damages to weirs / control structures as needed to assure proper flow conditions and operation. • Remove accumulated sediments to restore permitted storage volume and dispose of properly (3, 5). • Remove litter / debris as needed to assure proper flow conditions and operation and dispose of properly.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Pipes / Culverts

New systems (i.e., those in operation after the effective date of the permit)	Existing systems without chronic problems	Existing systems with chronic problems that affect the permitted operation of the system	
Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	FREQUENCY of INSPECTION
• Inspect pipes and culverts for structural deficiencies or damage that would prevent proper flow conditions and operation. • Inspect pipes and culverts to monitor sediment accumulation to prevent loss of storage volume and adverse impacts on flow and operation. • Inspect pipes and culverts to monitor vegetation and litter / debris accumulation to prevent loss of storage volume and adverse impacts on flow and operation. • Inspections of pipes and culverts can be done through a variety of methods, such as visual observations during normal operating conditions, TVing, mirroring, or other appropriate methods as set forth in the stormwater system operation and maintenance SOPs.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Repair any damages to pipes or culverts as needed to assure proper flow conditions and operation. • Remove accumulated sediments as needed to assure proper flow conditions and operation. Dispose of collected sediments properly (3, 5). • Remove vegetation and litter / debris as needed to assure proper flow conditions and operation and dispose of properly.			POSSIBLE MAINTENANCE ACTIVITIES (2)

Storm Sewer Inlets, Catch Basins, Grates, Ditches, Conveyance Swales, and Other Stormwater Conveyances			
New systems (i.e., those in operation after the effective date of the permit)	**Existing** systems **without chronic problems**	**Existing** systems **with chronic problems** that affect the permitted operation of the system	
Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	Inspect **a minimum of 10% of the total number of structures each year**. All of the structures shall be inspected at least once over two consecutive permit cycles (every 10 years)	FREQUENCY of INSPECTION
• Inspect for damage that would prevent proper flow conditions and operation. • Inspect and monitor sediment accumulation to prevent loss of storage volume and adverse impacts on flow and operation. • Inspect and monitor litter / debris accumulation to prevent loss of storage volume and adverse impacts on flow and operation. • Inspect vegetation on bottom and side slopes of conveyances to assure it is healthy, maintaining coverage, and that no erosion is occurring within the conveyance system.			POSSIBLE INSPECTION ACTIVITIES
As needed based on inspection to assure proper operation			FREQUENCY of MAINTENANCE
• Repair any damages to weirs / control structures as needed to assure proper flow conditions and operation. • Remove accumulated sediments to restore permitted storage volume and dispose of properly (3, 5). • Remove litter / debris as needed to assure proper flow conditions and operation and dispose of properly. • Maintain healthy vegetative cover to prevent erosion of the conveyance bottom or side slopes (4).			POSSIBLE MAINTENANCE ACTIVITIES (2)

NPDES Permit notes:

PART II. STORMWATER POLLUTION PREVENTION AND MANAGEMENT PROGRAMS

The SWMP shall include controls necessary to effectively prohibit the discharge of non-stormwater into the MS4 and reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable (MEP).

Structural Controls and Stormwater Collection System Operation: The MS4 and any stormwater structural control shall continue to be operated by the permittees in a manner to reduce the discharge of pollutants (including floatables) to the MEP.

a. **Each permittee**, except FDOT District Two, **shall comply with the applicable inspection and maintenance requirements in Table II.A.1.a Inspection And Maintenance Schedule For Structural Controls And Roadways for those controls operated by the permittee.** FDOT District Two shall comply with the inspection and maintenance requirements in Table II.A.1.a, or with the inspection and maintenance schedule as included in the revised and approved FDOT Statewide Stormwater Management Program that specifies minimum inspection frequencies