RESOLUTION No. 21-193

A RESOLUTION OF THE MAYOR AND THE CITY COUNCIL OF THE CITY OF DORAL, FLORIDA, ADOPTING THE CITY OF DORAL 2021 UPDATE TO THE LOW IMPACT DEVELOPMENT (LID) MASTER PLAN; AND PROVIDING FOR AN EFFECTIVE DATE

WHEREAS, on February 2, 2015, the City of Doral and ADA Engineering entered into a professional services agreement to develop a Low Impact Development (LID) Master Plan in order to minimize the impacts of development on the environment, which includes but is not limited to, soil erosion, increase in pervious areas and reduction of green areas, reduction on ground water recharge, increase flooding, and degradation in water quality; and

WHEREAS, on November 2, 2016, the Mayor and City Council adopted the City's Low Impact Development (LID) Master Plan via Resolution No. 16-229; and

WHEREAS, on June 21, 2019, the City of Doral retained ADA Engineering to update Section 74-881, "Low Impact Development (LID) Practices" and update the City's Low Impact Development Master Plan; and

WHEREAS, on December 2, 2020, the City of Doral hosted a community and stakeholder workshop to obtain input from the community and developers to build consensus on the final recommendations of the LID Master Plan update; and

WHEREAS, the 2021 Update to the LID Master Plan includes two (2) new LID best management practices (BMPs), revised the analysis approach for up to two (2) LID BMPs, and updated hydrologic/hydraulic models from ICPRV3 to ICPRV4; and

WHEREAS, the Mayor and City Council finds that adopting the 2021 Low Impact Development Master Plan Update is in the best interest of the City.

NOW THEREFORE, BE IT RESOLVED BY THE MAYOR AND THE CITY COUNCIL OF THE CITY OF DORAL, FLORIDA, AS FOLLOWS:

Section 1. **Recitals.** The foregoing recitals are confirmed, adopted, and incorporated herein and made as part hereof by this reference.

Section 2. **Adoption.** The Mayor and City Council of the City of Doral hereby adopt the 2021 Update to the City's Low Impact Development (LID) Master Plan, a copy of which is attached hereto as "Exhibit A."

Section 3. **Effective Date.** This Resolution shall become effective immediately upon its adoption.

The foregoing Resolution was offered by Vice Mayor Cabrera who moved its adoption. The motion was seconded by Councilmember Cabral and upon being put to a vote, the vote was as follows:

Mayor Juan Carlos Bermudez	Yes
Vice Mayor Pete Cabrera	Yes
Councilwoman Digna Cabral	Yes
Councilwoman Claudia Mariaca	Yes
Councilman Oscar Puig-Corve	Absent/Excused

PASSED AND ADOPTED this 25 day of August, 2021.

JUAN CARLOS BERMUDEZ, MAYOR

ATTEST:

CONNIE DIAZ, MMC
CITY CLERK

APPROVED AS TO FORM AND LEGAL SUFFICIENCY
FOR THE USE AND RELIANCE OF THE CITY OF DORAL ONLY:

LUIS FIGUEREDO, ESQ.
CITY ATTORNEY

EXHIBIT “A”

EXHIBIT A

City of Doral

Low Impact Development Master Plan

Prepared by:

A·D·A ENGINEERING

8550 NW 33rd Street, Suite 202
Doral, Florida 33122

Updated August 2021

City of Doral
Low Impact Development Master Plan
Draft Report

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1.0 EXECUTIVE SUMMARY

The City of Doral (City) was incorporated in 2003 and is located in the western-central portion of Miami-Dade County. The City is roughly bounded by NW 90th Street to the north, the Florida Turnpike to the west, State Road 836 (Dolphin Expressway) to the south, and State Road 826 (Palmetto Expressway) to the east. The City of Doral comprises a total area of approximately 15 square miles.

The preliminary estimated population for 2016 is 59,304. This represents an increase of approximately 6.7% from last year's population estimates (55,586). By 2020, the estimated population for the city is approximately 78,668 residents. Despite this growth, the City has ample inventory of planned dwelling units and vacant land to accommodate future growth through 2025. Beyond 2025, the City may experience reduced growth unless additional residential capacity is added through annexation and/or redevelopment.

Presently, the city is experiencing significant growth in residential and non-residential development. This includes a new downtown, several major mixed-use developments (PUDs and TND projects), commercial mixed-use projects, and redevelopment projects along Doral Boulevard and NW 58th Street.

This rapid land development and urbanization will have an impact on the natural urban hydrologic processes of surface water runoff patterns, infiltration, percolation to ground water, and evapotranspiration. Under predevelopment conditions, up to half of the annual rainfall infiltrates through the sandy soils and percolates downward where portions of it recharge the ground water. In contrast, developed areas can generate up to five times the annual runoff and only allow one-third the pre-development infiltration of natural areas.

This change will have a potential negative impact to the environment, which includes but is not limited to, soil erosion, increase in impervious areas, reduction in open space and recreational areas, reduction on ground water recharge, increase of potential flooding, and degradation in water quality. Minimizing these environmental impacts by reducing the overall imperviousness, applying new techniques, and using natural drainage features on site is one of the major goals of the City and an important design strategy to maintain the pre-development site hydrologic characteristics after development to the maximum extent practicable. This goal can be accomplished by applying various proven Low Impact Development (LID) planning strategies for storm water management.

The purpose of this project is to develop a LID Master Plan to assist the City in maximizing implementation of LID Integrated Management Practices. These practices will minimize impacts from anticipated new development and/or redevelopment projects. The Master Plan will also provide guidance for LID site planning, hydrologic analysis, and erosion and sediment control practices, as well as incentives for participation.

The scope of work to develop the Low Impact Development Master Plan was subdivided into the following key tasks:

- Task 1 – Project Coordination and Progress Meetings
- Task 2 – Data Collection and Evaluation
- Task 3 – Low Impact Development Site Planning
- Task 4 – Low Impact Development Hydrologic Analysis
- Task 5 – Low Impact Development Integrated Management Practices
- Task 6 – Low Impact Development Erosion and Sediment Control Management practices
- Task 7 – Public Involvement and Outreach Programs
- Task 8 – Low Impact Development Master Plan Report

In 2019, the City of Doral retained A.D.A. Engineering, Inc. (ADA) to update the 2016 LID Master Plan Report. Updates were based on input from the development community and City staff following meetings and public workshops.

The following sub-sections include a summary of the work completed under each task for the original 2016 Low Impact Development Master Plan.

1.1 Task 1 – Project Coordination and Progress Meetings

The City of Doral retained A.D.A. Engineering, Inc. (ADA) to provide the services identified below for the project entitled "Low Impact Development Master Plan" in accordance with City of Doral Continuing Professional Services Final Agreement RFQ#2014-24 dated March 2, 2015.

As part of this Task, ADA attended bi-monthly progress meetings to provide for general project coordination and work planning. The status of all ongoing tasks and City reviews were discussed at these meetings, as well as all issues related to draft deliverables and comments received from the City regarding such deliverables.

1.2 Task 2 – Data Collection and Evaluation

Data was requested and acquired from the various sources maintaining data within Miami-Dade County and the State of Florida, as well as from the City of Doral. The collected data was cataloged, evaluated, and utilized as needed to support the analyses and preparation of the Low Impact Development Master Plan Report. Data was requested and/or collected from the following entities:

- Miami-Dade County
- City of Miami Beach
- City of Orlando
- City of Sanford
- City of Tampa
- Alachua County
- Hillsborough County
- Orange County
- Pinellas County

- Sarasota County
- South Florida Water Management District
- Environmental Protection Agency
- Florida Department of Environmental Protection
- Florida Water Star Program

In addition to the data collected, ADA also performed a literature search of available documented data that was presented at the American Society of Civil Engineers (ASCE) and the Environmental and Water Resources Institute (EWRI) conference held in San Francisco, California in April 11–14, 2010. The documented research contained pertinent and applicable data related to LID management practices. The technical papers presented during this conference addressed a broad range of topics that are relevant to a sustainable approach to stormwater management using the LID technology. These topics include:

- LID and Sustainability
- Overcoming Institutional and Other Barriers to LID Implementation
- Codes, Regulations, Constraints, Guidelines
- Recent Monitoring / Performance Findings
- Computational Methods
- Advances in LID Best Management Practice (BMP) Design Methods – Lessons Learned
- Site Design Considerations
- LID Incentives for New Developments
- Watershed Retrofit with LID
- Education and Training Outreach
- Long-Term Performance, Maintenance

1.3 Task 3 – Low Impact Development Site Planning

Implementation of LID begins at the planning level of the site development or redevelopment process. One of the first steps in site planning involves taking inventory of the existing features on the site including topography, soil characteristics, flow paths, drainage features, building and stormwater infrastructure, impervious areas, open spaces, and vegetation. Through LID techniques, developments are designed to be integrated with these existing features and to retain or simulate the pre-development site conditions.

LID design techniques include both structural and non-structural hydrologic controls that compliment traditional stormwater treatment and conveyance systems by utilizing pre-development hydrological features to decentralize and micromanage stormwater runoff at its source. Throughout the site development process, alternative design options that include LID techniques or LID techniques combined with traditional stormwater management infrastructure are evaluated and integrated into the site plan to the greatest extent possible. The overall LID site planning development process includes:

- Identification and compliance with existing site planning regulations and ordinances,
- Assessment and inventory of pre-development site conditions,
- Development of the preliminary site plan,
- Minimization of directly connected impervious areas (DCIA),
- Evaluation and implementation of Best Management Practices (BMPs), these are LID management techniques employed to achieve the desired post-development hydrologic condition,
- Comparison of pre-development and post-development hydrology, and
- Completion of LID Site Plan.

The primary nonstructural LID site planning practices and considerations that appear to be most applicable to the City of Doral include the following:

1. Restoration and preservation of pre-development topography and soil profile
2. Preservation and use of native and local vegetation
3. Open space design and conservation
4. Minimization of total impervious areas
5. Reduction of DCIA

The primary structural LID BMPs and practices that appear to be most applicable to the City of Doral include the following:

- Bioretention Basins or Rain Gardens
- Tree Box Filters or Infiltration Planters
- Vegetated Swales
- Filter Strips or Vegetated Buffers
- Infiltration Trench
- Exfiltration Trench or French Drains
- Green Roofs/Rain Barrels or Cisterns
- Permeable Pavement
- Detention Ponds
- Parking Chambers

1.4 Task 4 – Low Impact Development Hydrologic Analysis

Conventional stormwater management techniques are typically sited at the most downstream end of the entire site (typically end of pipe control). The requirement is usually to provide the required water quality retention volume and maintain the post-development peak runoff rates in cubic feet per second (cfs) at or below the pre-development rates for a particular 24- or 72-hour design storm event. Under this approach, the peak runoff rate will not be increased; however, the post-development runoff volume is usually greater than the pre-development volume. This is because the typical drainage systems are designed to control the peak flow runoff rate, but overall the systems discharge a larger runoff volume because the flows are just discharged over a longer duration. For this reason, the recommended hydrologic analysis approach to assess LID BMPs is to implement a pre- versus post-development runoff volume approach using an average annual rainfall event. This approach is best suited to assess the structural LID BMPs because these type of BMPs are aimed to control or retain smaller rainfall events, which constitute about 80% of the annual amount of rainfall for a typical average year in south Florida.

The purpose of implementing an LID approach is to match pre-development conditions by compensating for losses of rainfall abstraction through maintenance of infiltration potential, evapotranspiration, and surface storage as well as increased travel time to reduce rapid concentration of excess runoff and impacts to downstream drainage systems such as the City’s drainage systems located within the City’s right-of-way areas.

The implementation of LID techniques aims to control smaller and more frequent rainfall events. These events are usually less than a 2-year return period, but generate most of the annual runoff from an urban watershed.

1.5 Task 5 - Low Impact Development Integrated Management Practices

Current site development or redevelopment projects must meet, at a minimum, the stormwater quality and flood protection requirements outlined by South Florida Water Management District (SFWMD), Miami-Dade County Department of Regulatory and Economic Resources (DRER), and City of Doral. The water quality requirement is to provide retention of one inch of runoff over the entire site or 2.5 inches over the impervious areas, whichever is greater. For flood protection, at a minimum, roads and parking areas must be built at or above the 5-year, 24-hour design peak stage, the post-development runoff rate cannot exceed the pre-development rate, and the building finish floor elevations must be set at or above the 100-year, 3-day design storm event or the Federal Emergency Management Agency (FEMA) flood elevation, whichever is greater.

Prior to this LID Master Plan, the City of Doral had no specific requirements for implementing LID techniques. As part of the LID Master Plan, the City now requires non-structural LID practices be implemented in new developments to the maximum extent practicable. If not practical, developers must demonstrate that the practices cannot be implemented because of site constraints, and not due to financial impacts. Developments incorporating LID techniques are required to adhere to the same ordinances, zoning regulations, water quality and quantity requirements, and land use designations as developments designed utilizing traditional stormwater management techniques.

1.6 Task 6 – Low Impact Development Erosion and Sediment Control Management Practices

The City of Doral participates as a co-permittee with Miami-Dade County in the National Pollution Discharge Elimination System (NPDES) program. The program is aimed at improving stormwater runoff water quality and control erosion from construction activities. The City of Doral must address specified activities and program compliance stated within the Annual Reports and NPDES permit conditions.

The application of LID concepts and the associated emphasis on minimizing the areas disturbed, as well as breaking up drainage areas into small manageable sub-catchment areas, is in agreement with the basic principles of erosion and sediment control. The application of LID technology can easily result in improved erosion and sediment control without significant additional effort.

An effective sediment and erosion control plan is essential for controlling stormwater pollution during construction. An erosion and sediment control plan is a site-specific plan that specifies the location, installation, and maintenance of best management practices to prevent and control erosion and sediment loss at a construction site.

1.7 Task 7 – Public Involvement and Outreach Programs

The City of Doral and the ADA Team implemented a pro-active Public Involvement and Outreach Program to educate the public and local land developers in the activities that were being performed to complete this LID Master Plan and to obtain feedback from the residents and land developers. The public involvement task included coordinating and conducting (2) workshops with the intent of providing a relaxed and comfortable venue where participants could focus on the LID Master Plan process and goals, solicit feedback, and discuss future improvements for the City.

Objectives of the community workshops included:

- Conducting an integrated Public Involvement and Community Outreach (public interaction) program;
- Engaging the community in an open, healthy dialogue about the project, emphasizing that the City of Doral bases the final decision on several criteria, and community input is important to them;
- Fostering understanding of the City of Doral's responsibility now and into the future with its LID Master Plan;
- Helping build communities based on environmental stewardship;
- Discussing ways of minimizing impacts on stakeholders and preventing opposition to future LID planning and design strategies;
- Communicate to stakeholders the need for implementing LID best management practices and how they benefit the community; and
- Explain the engineering and planning process to achieve environmental sustainable development.

In addition to the resident and developer workshops, individual meetings were held with elected officials. The LID Plan was also available for public inspection for more than six weeks in the City’s website. Thereafter, the project was presented to the Mayor and the City Council on October 28, 2016 at regular council meeting.

1.8 Conclusions and Recommendations

The rapid land development and urbanization taking place in the City of Doral will have an impact on the natural urban hydrologic processes of surface water runoff patterns, infiltration, percolation to ground water, and evapotranspiration. Low Impact Development takes an innovative approach to mitigating these impacts and seeks to retain runoff and treat stormwater pollution at the source. The purpose of the LID Master Plan is to provide the City of Doral with guidelines and recommendations to adopt integrated LID BMPs and green infrastructure practices in future development sites.

The City of Doral has one ordinance (Ord. No. 2013-37, § 2, 12-3-2014) for the incorporation of LID practices into building plans, project designs, and site plans. The ordinances mandate that LID practices be included as part of site development plan, and provide provisions for rainfall harvesting facilities. The current Site Planning Regulations are hereby recommended to be amended with the addition of a requirement for a hydrological assessment of the pre- versus post-development conditions, implementation of a Site LID Design Strategies Checklist document into the current permit application, and the addition of more substantial details for the implementation of LID requirements, as well as provisions for sites where LID techniques are technically infeasible.

In addition, it is recommended that provisions for long-term maintenance, monitoring, and enforcement be developed. Long-term maintenance and inspection plans are required for LID systems and the entity responsible for the maintenance and monitoring should be clearly defined. Site Planning Regulations should be evaluated to minimize the requirements for property setbacks, traffic distribution network widths, sidewalk widths, and right-of-way areas.

Based on the data previously collected and evaluated, non-structural and structural LID planning practices were identified that will naturally treat and retain stormwater for new developments and redevelopment sites. The site planning process should incorporate LID strategies in each step of the process. The recommended priority for managing and capturing stormwater runoff is infiltration, evapotranspiration, capture and use, and treatment through biofiltration/bioretention systems.

Based on a review of the current City of Doral LID ordinance and LID management practices, the City’s current site development approach does not require any LID BMP implementation or provide any guidelines. In the City of Doral, there are no requirements for minimum vegetated/stormwater management space for commercial or residential land use development, the water quality retention requirement is the first 1 inch of runoff, and the stormwater management system is required to meet pre- versus post-development peak discharge flow only.

The City of Doral implements standard on-site practices for erosion and sediment control, which include inlet protection systems, silt fence, turbidity barriers, and temporary gravel construction entrances and exits. However, it is recommended that the City include other erosion control practices, such as soil stabilization and runoff control. The recommended measures effectively isolate the development site from surrounding properties and control sediment where it is produced, thus preventing its transport from the site. Diversions, berms, sediment traps, vegetative filters, and sediment basins are examples of practices to control sediment. Vegetative and structural sediment control measures are either temporary or permanent, depending on whether they will remain in use after development is complete. Generally, sediment is retained by (a) filtering runoff as it flows through an area and (b) impounding the sediment-laden runoff for the soil particles to settle. The most effective method to control sediment, however, is to prevent erosion

2.0 INTRODUCTION

2.1 Background

The City of Doral was incorporated in 2003 and is located in the western-central portion of Miami-Dade County. The City is roughly bounded by NW 90th Street to the north, the Florida Turnpike to the west, State Road 836 (Dolphin Expressway) to the south, and State Road 826 (Palmetto Expressway) to the east – see **Figure 2-1**. The City of Doral encompasses a total area of approximately 15 square miles.

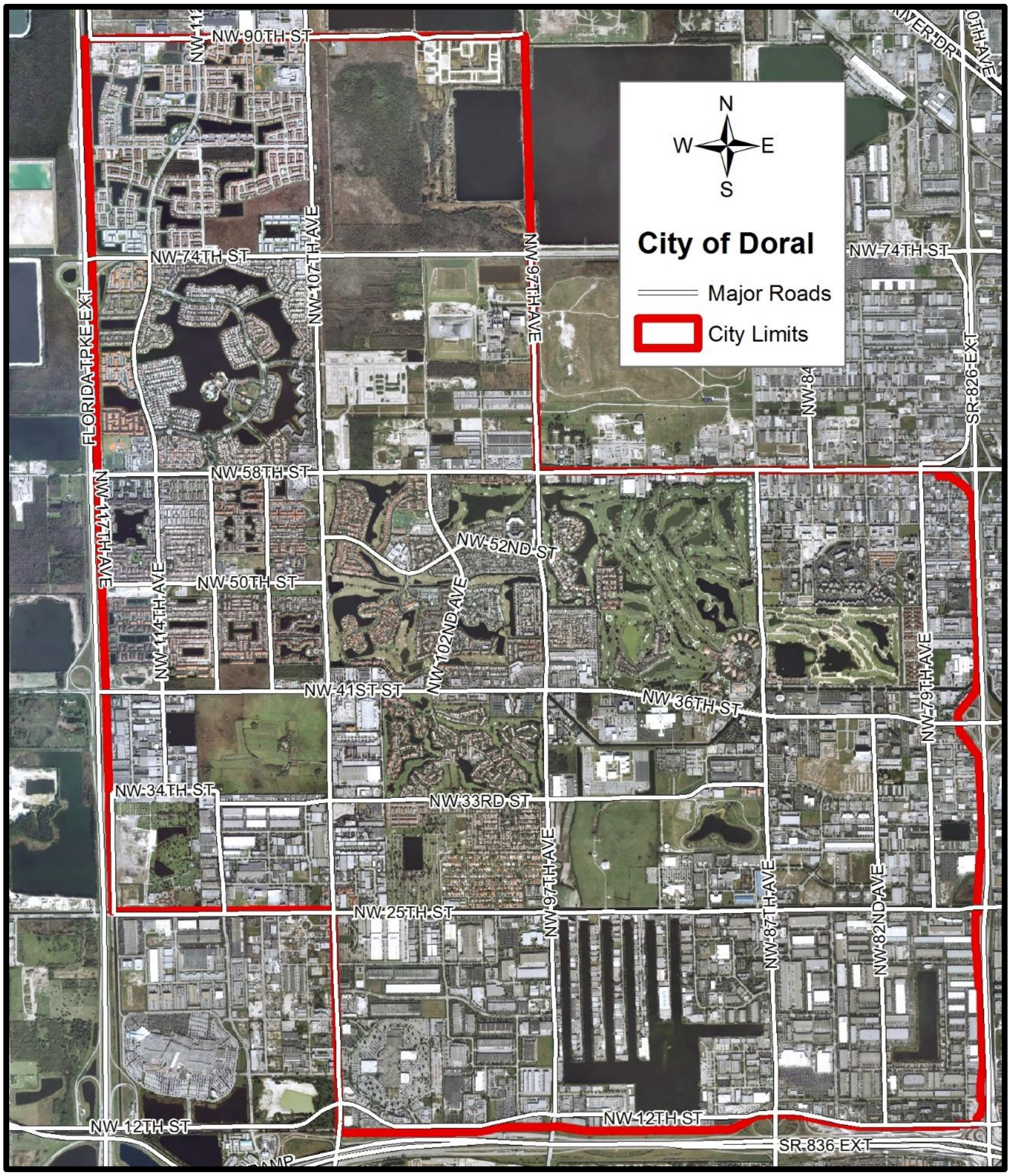

Figure 2-1 – Major Roads within the City of Doral

The City is located within the boundaries of the SFWMD, C-4 and C-6 Drainage Basins – see **Figure 2-2**. Both the C-4 Canal and C-6 Canal are SFWMD primary canals. These canals primarily flow from the Everglades conservation areas to Biscayne Bay. There are three main secondary canals which convey stormwater within the City: C-2 Extension Canal (Snapper Creek Canal) along NW 17th Avenue, Northline Canal located immediately north of NW 25th Street which discharges to the C-4 Canal, and Dressels Canal which connects to the FEC Canal. These canals are operated by Miami-Dade County.

The main conveyance in the C-4 Basin is the C-4 Canal (Tamiami Canal), and the main conveyance in the C-6 Basin is the C-6 Canal (Miami River). The City's primary and secondary drainage systems discharge to these two major watersheds. These watersheds are at their maximum hydraulic capacity and ultimately discharge to Biscayne Bay, an Outstanding Florida Waterbody. It is imperative that LID planning practices are implemented for future development and redevelopment to minimize impacts to these sensitive watersheds.

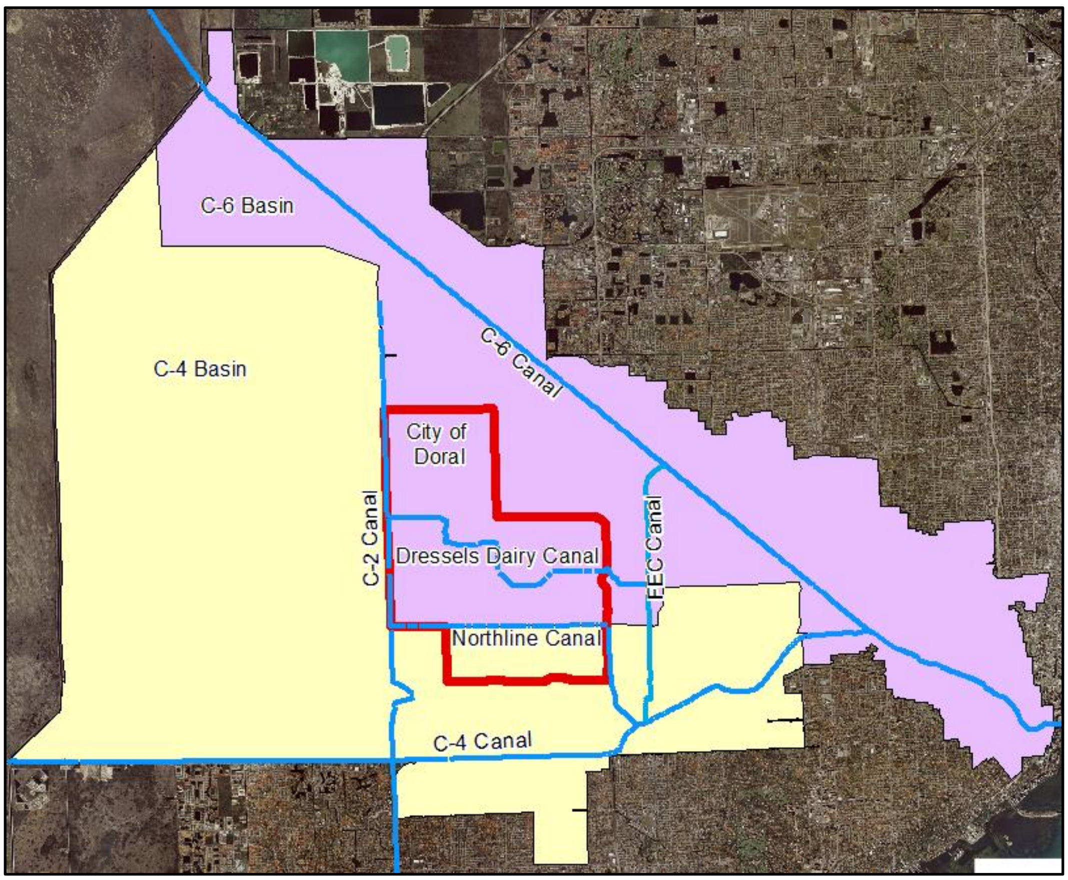

Figure 2-2 – SFWMD Canal Basins & City of Doral Limits

The City's residential, commercial/industrial, and mixed-use land uses account for approximately 83% of the City's total area based on the 2015 land use GIS shapefile available from the City – see **Table 2-1** for existing land use distribution.

Table 2-1 – Land Use Distribution within the City of Doral

Land Use	Area (sq. mi)	% of City
Residential	4.9	33%
Commercial / Industrial	6.1	41%
Parks	1.8	12%
Institutional / Public	0.8	5%
Mixed Use	1.3	9%
Total	**14.9**	**100.0%**

The City is currently one of the fastest growing young cities in the United States. It is anticipated that this will continue into the next three to five years as newly approved major mixed-use development projects such as Downtown Doral, Park Square, Grand Bay North and South, and Midtown will attract more people to the City. These development projects will generate between 8,000 and 9,000 new units between 2014 and 2025.

In addition, more than 1,000 hotel apartments are expected to be built from 2014-2020. The non-residential component is expected to generate over 1.0 million square feet of retail and 2.0 million square feet of office space. The City anticipates that the existing non-residential development estimates will change within the next five years because of changes in the real estate market for such uses. The City is also entering a redevelopment phase along major commercial corridors such as Doral Boulevard and NW 58th Street that will create more opportunities for more mixed-use development and commercial/retail uses.

This rapid land development and urbanization will have an impact on the natural urban hydrologic processes of surface water runoff patterns, infiltration, percolation to ground water, and evapotranspiration. Under predevelopment conditions, up to half of the annual rainfall infiltrates through the sandy soils and percolates downward where portions of it can recharge the ground water. In contrast, developed areas can generate up to five times the annual runoff and only allow one-third the pre-development infiltration of natural areas.

This change will have a potential negative impact to the environment, which includes but is not limited to, soil erosion, increase in impervious areas, reduction in open space and recreational areas, reduction on ground water recharge, increase of potential flooding, and degradation in water quality. Minimizing these environmental impacts by reducing the overall imperviousness, applying new techniques, and using natural drainage features on site is one of the major goals of the City and an important design strategy to maintain the pre-development site hydrologic characteristics after development as much as possible. This goal can be accomplished by applying various LID planning strategies for storm water management.

2.2 Low Impact Development Master Plan Purpose and Scope

The basic traditional engineering approach to storm water management conveys runoff rapidly from developed surface into man-made drainage structures designed to accommodate a large volume of storm water and pollutant to a discharge area. In contrast, LID takes a different approach than conventional stormwater management by using the natural environment within the sites being developed or redeveloped to recreate as much as possible the predevelopment natural hydrologic processes and reduce the disruptive effects of urban runoff patterns.

The purpose of this project is to develop a LID Master Plan to assist the City in maximizing implementation of LID Integrated Management Practices (IMPs). These practices will minimize impacts from anticipated new development and/or redevelopment projects. The Master Plan will also provide guidance for LID site planning, hydrologic analysis, and erosion and sediment control practices, as well as incentives for participation. As part of the Master Plan development, a Public Outreach Program was implemented to educate the residents and developers regarding the benefits of implementing LID practices and obtain input from these stakeholders to build consensus on the final recommendations of the LID Master Plan.

A.D.A. Engineering, Inc. (ADA) was contracted by the City of Doral to complete the LID Master Plan for the City, in accordance with City of Doral Continuing Professional Services Final Agreement (RFQ#2014-24) dated March 2, 2015. The LID Master Plan was subdivided into eight tasks with the final task consisting of preparing the final LID Master Plan Report. The results and findings of each primary task were summarized in five task specific Technical Memorandums (TM). The Technical Memorandums prepared as part of this LID Master Plan are as follows:

- Technical Memorandum No. 1 – Data Collection and Evaluation
- Technical Memorandum No. 2 – Low Impact Development Site Planning
- Technical Memorandum No. 3 – Low Impact Development Hydrologic Analysis
- Technical Memorandum No. 4 – Low Impact Development Integrated Management Practices
- Technical Memorandum No. 5 – Low Impact Development Erosion and Sediment Control Management Practices
- Final Low Impact Development Master Plan Report

The scope of work to develop the Low Impact Development Master Plan was subdivided into the following key tasks:

- Task 1 – Project Coordination and Progress Meetings
- Task 2 – Data Collection and Evaluation
- Task 3 – Low Impact Development Site Planning
- Task 4 – Low Impact Development Hydrologic Analysis
- Task 5 – Low Impact Development Integrated Management Practices
- Task 6 – Low Impact Development Erosion and Sediment Control Management Practices
- Task 7 – Public Involvement and Outreach Programs
- Task 8 – Low Impact Development Master Plan Report

The following sub-sections include a summary of the work completed under each of these tasks, and detailed descriptions are included in **Section 2.0** through **Section 8.0** of the Final Low Impact Development Master Plan Report.

In 2019, the City of Doral retained A.D.A. Engineering, Inc. (ADA) to update the 2016 Low Impact Development Master Plan Report. Updates were based on input from the development community and City staff following meetings and public workshops. Updates have been integrated into the Low Impact Development Master Plan report, and include added detail and analysis methodologies for Best Management Practices (BMPs), as well as examples of implemented BMPs within the City. In addition, the hydrologic/hydraulic model used in the sample analyses was converted from ICPR3 to ICPR4.

2.2.1 Task 1 – Project Coordination and Progress Meetings

The City of Doral retained A.D.A. Engineering, Inc. (ADA) to provide the services identified below for the project entitled “Low Impact Development Master Plan” in accordance with City of Doral Continuing Professional Services Final Agreement RFQ#2014-24 dated March 2, 2015.

As part of this Task, ADA attended bi-monthly progress meetings to provide for general project coordination and work planning. The status of all ongoing tasks and City reviews will be discussed at these meetings, as well as all issues related to draft deliverables and comments received from the City regarding such deliverables.

2.2.2 Task 2 – Data Collection and Evaluation

The purpose of this task, *Technical Memorandum No. 1 - Data Collection and Evaluation*, was to request and collect readily available data that would support the development of the LID Master Plan. ADA reviewed the data collected and assessed its relevance for inclusion as a part of this project.

As part of this task, ADA performed a literature search of currently available LID practices and standards. In addition, ADA performed an inter-municipal research on already implemented LID techniques with the purpose to identify LID practices that are best applicable and beneficial to the South Florida environment and hydrology.

The collected data was cataloged, evaluated, and utilized as necessary to support the analyses and preparation of the subsequent Technical Memorandums and the final LID Master Plan Report.

2.2.3 Task 3 – Low Impact Development Site Planning

The purpose of this task, *Technical Memorandum No. 2 - Low Impact Development Site Planning*, was to evaluate the City’s current Site Planning Regulations and identify areas where the current regulations could be amended and modified to include sustainable LID practices.

As part of this TM, the data collected as part of TM1, Data Collection and Evaluation, non-structural and structural LID planning practices most applicable to the City were identified to naturally treat and retain stormwater from new development and redevelopment sites, and provide incentive for implementing environmentally sensitive site planning and design. This TM also documented the advantages and disadvantages of each of the LID practices identified

2.2.4 Task 4 – Low Impact Development Hydrologic Analysis

The purpose of this task, *Technical Memorandum No. 3 - Low Impact Development Hydrologic Analysis,* is to identify and document the hydrologic analysis procedures to be implemented in analyzing the structural LID BMPs identified and explained in detail in TM#2 Site Planning.

As part of this TM, the recommended computation procedures were documented and included an example of a recently permitted development project to illustrate the application of these procedures. The example includes the same development with and without LID BMPs to document the benefits provided by the LID BMPs.

2.2.5 Task 5 – Low Impact Development Integrated Management Practices

The purpose of this task, *Technical Memorandum No. 4 - Low Impact Development Integrated Management Practices,* is to provide the City with detailed descriptions, application standards, standard details, and recommend operation and maintenance of these BMPs. Also, provide recommendations to promote incentives to encourage environmentally sustainable site planning using these LID practices. ADA provided recommended regulation language to be implemented in the current LID Regulations to allow for innovating engineering and planning principles.

2.2.6 Task 6 – Low Impact Development Erosion and Sediment Control Management Practices

The purpose of this task, *Technical Memorandum No. 5 - Low Impact Development Erosion and Sediment Control Management Practices,* is to evaluate the City's current construction phase soil erosion and sediment control standards and identify areas where the current regulations can be amended and modified to include sustainable soil erosion and sediment control LID practices.

ADA used the data collected as part of Task 2 to identify supplemental or refined LID construction phase soil erosion and sediment control practices to be incorporated by the City. The recommended regulation language to be implemented in the current LID regulations to allow for innovative soil erosion and engineering implementation principles are documented and included in this report.

2.2.7 Task 7 – Public Involvement and Outreach Programs

The City of Doral and the ADA Engineering Team implemented a Public Involvement and Outreach program to educate the public and local land developers in the activities that were being performed to complete this LID Master Plan and to obtain feedback and input from the residents and developers. The public involvement task included coordinating and conducting one (1) Resident Workshop and one (1) Developer Workshop with the intent of providing a venue where participants could understand the LID Master Plan process and goals, solicit feedback, discuss future improvements, and develop a positive rapport with community stakeholders.

Some of the objectives of the Resident Workshop included:

- Foster an understanding of the City of Doral's implementation of LID Integrated Management Practices, the benefits to the community, and the engineering process;
- Minimize impact on businesses and stakeholder opposition to the proposed protocols;
- Communicate to stakeholders the need for implementation of LID site planning, hydraulic analysis, and erosion control practices;
- Engage the community in an open, healthy dialogue about the project, convey that the City of Doral bases the final decision on several criteria, and that community input is an important part of those criteria.

Attachment A includes a summary of the Resident and Developer Workshops.

3.0 DATA COLLECTION AND EVALUATION

The data collection task required collecting available data from entities in the State of Florida that have implemented or have experience with LID management practices. Data was requested and/or collected from the flowing entities:

- Miami Dade County
- City of Miami Gardens
- City of Miami Beach
- City of Orlando
- City of Sanford
- City of Tampa
- Alachua County
- Hillsborough County
- Orange County
- Pinellas County
- Sarasota County
- South Florida Water Management District
- Environmental Protection Agency
- Florida Department of Environmental Protection
- Florida Water Star Program

The following information was requested:

- LID management practices to naturally treat and retain stormwater from new developments and redevelopment sites,
- Structural and non-structural BMPs implemented,
- Incentives provided for implementing environmentally sensitive site planning and design, and
- Performance/feedback from LID practices implemented.

Attachment B includes a matrix of all entities contacted. This matrix includes point of contact, data requested, and status of request.

3.1 ASCE/EWRI Conference

As part of the data collection, ADA also performed a literature search of available documented data that was presented at the American Society of Civil Engineers (ASCE) and the Environmental and Water Resources Institute (EWRI) conference held in San Francisco, California in April 2010. The documented research contained pertinent and applicable data related to LID management practices. The technical papers presented during this conference addressed a broad range of topics that are relevant to a sustainable approach to stormwater management using the Low Impact Development technology. These topics include:

- LID and Sustainability

- Overcoming Institutional Barriers and Other Barriers to LID Implementation
- Codes, Regulations, Constraints, Guidelines
- Recent Monitoring / Performance Findings
- Computational Methods
- Advances in LID BMP Design Methods – Lessons Learned
- Site Design Considerations
- LID Incentives for New Developments
- Watershed Retrofit with LID
- Education and Training Outreach
- Long-Term Performance, Maintenance

Attachment C provides the following ASCE/EWRI key technical papers which were selected to support the development of this LID Master Plan:

- *ASCE-EWRI Permeable Pavement Technical Committee – Introduction of Committee Goals and Chapter 1 of Guidelines "Design Considerations Common to All Permeable Pavements".* Bethany E. Eisenberg
- *Considerations in Selecting a (Bio)Filtration Media to Optimize Lifespan and Pollutant Removal*. Shirley E. Clark and Robert Pitt.
- *Pervious Asphalt Roads and Parking Lots: Stormwater Design Configurations*. A. L. Broadsword and C. A. Rhinehart,
- *Pervious Pavement Systems in Florida – Research Results*. Manoj B. Chopra, Erik Stuart, and Martin P. Wanielista.
- *The Urban Green BioFilter: An Innovative Tree Box Applications.* James H. Lenhart, Scott A. deRidder, and Vaikko Allen.
- *A Non-Dimensional Modeling Approach for Evaluation of Low Impact Development from Water Quality to Flood Control*. T. Andrew Earles, James Guo, Ken MacKenzie, Jane Clary, and Shannon Tillack.
- *Comparison of BMP Infiltration Simulation Methods*. Jenny Zhen, Mow-Soung Cheng, John Riverson, and Jenny Zhen.
- *Planning-Level Cost Estimates for Green Stormwater Infrastructure in Urban Watersheds.* M. J. Vanaskie, R. D. Myers, and J. T. Smullen.
- *LID, LEED and Alternative Rating Systems – Integrating Low Impact Development Techniques with Green Building Design.* Laura Prickett and Jill Bicknell.
- *Evaluation of Roadside Filter Strips, Dry Swales, Wet Swales, and Porous Friction Course for Stormwater Treatment.* R. J. Winston, W. F. Hunt, and J. D. Wright.
- *Expanding the International Stormwater BMP Database Reporting, Monitoring, and Performance Analysis Protocols to Include Low Impact Development (Part 1).* Jane Clary, Marcus Quigley, Andrew Earles, Jonathan Jones, Eric Strecker, and Aaron Poresky.
- *Low Impact Development Benefits of Level Spreader – Vegetative Filter Strip Systems*. Ryan J. Winston and William F. Hunt.

The technical papers provided by ASCE/EWRI were evaluated for relevance to the application of non-structural and structural LID planning practices for the natural treatment and retention of stormwater at new development and redevelopment sites. The papers also gave insight into the incentives provided for implementing environmentally sensitive site planning and design practices. From a collection of 50 technical papers presented at the conference, 12 of the most relevant to the topics were selected for review.

3.2 Miami-Dade County

Miami-Dade County Planning Department provided information related to the recently updated Comprehensive Development Master Plan (CDMP). The amendments adopted on October 2, 2013 include many of the principles of LID management practices, sustainability and green building, and information on policies related to specific aspects of LID. The CDMP can be accessed at http://www.miamidade.gov/planning/cdmp-adopted.asp.

3.3 Pinellas County

In 2006 Pinellas County became the first jurisdiction in the State of Florida to be designated a Green Local Government by the Florida Green Building Coalition (FGBC). LID management practice programs contribute to the County's sustainability commitment in a time when the current redevelopment trends are increasing rapidly and reaching a state of build-out. Redevelopment in Pinellas County represents a particularly suitable opportunity for implementing LID practices on a lot-by-lot level. Some examples of LID practices that apply to individual lots include green roofs, cisterns or rain barrels, micro-irrigation, bioretention systems, and pervious pavers.

3.4 Sarasota County

Although LID stormwater management practices are not mandatory in Sarasota County, they encourage the use of LID practices, where possible, to help meet its water resource objective. The LID Manual developed is expected to be adopted by the Sarasota County Board of County Commissioners, and to be incorporated by reference into the Sarasota County ordinance. The manual can be found at https://www.scgov.net/WaterServices/Pages/LowImpactDevelopment.aspx.

This manual supports Sarasota County's goal of applying the LID concept and design where feasible to enhance existing stormwater management measures and reduce the adverse impacts of land development projects on the county's natural resources. The main LID management practices targeted include:

- Stormwater Reuse
- Bioretention
- Green Roofs
- Swales
- Compost Filters
- Tanks / Vaults
- Porous Pavements
- Soil Amendments

- Fertilizer Control / Drip Irrigation
- Florida Friendly Yards
- Curb Elimination
- Disconnected Impervious Areas
- Reduced Street Width
- Cisterns and Rain Barrels

3.5 South Florida Water Management District (SFWMD)

The SFWMD provided information related to the topics recently discussed at the Regional Integration Workshop held in Ft. Lauderdale in October 2014. The workshop focused primarily on addressing sea level rise and implementation of structural and non-structural BMPs. In addition, the following topics were covered more in depth:

- Installation of flap gates at ocean outlets to minimize storm surge backwater effects
- Shifting from a gravity-drained system to pumped drainage (i.e. municipal pumping)
- Lowering pre-storm water levels (pre-storm drawdown)

3.6 Environmental Protection Agency (EPA)

Existing LID design and guidelines studies were available via the *Water and Pollution and Prevention Control* website. This website contains supporting documentation for implementation, design and guidance manuals for LID management practices. The following data was acquired through the EPA LID portal (http://water.epa.gov/polwaste/green/):

- Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs.
- Reducing Stormwater Costs through Low Impact Development Strategies and Practices
- Low Impact Development Design Strategies: An Integrated Design Approach
- Low Impact Development Urban Design Tools
- Low Impact Development Manual
- Field Evaluation of Permeable Pavements for Stormwater Management

3.7 Florida Department of Environmental Protection (FDEP)

The FDEP and the Water Management Districts are developing statewide stormwater treatment rules to address growing concerns about nutrient over-enrichment of Florida's surface waters, groundwater, and springs. This rule is a significant step forward in the control of nutrient loadings from stormwater discharges. The draft rule and Applicant's Handbook can be found at http://www.dep.state.fl.us/WATER/wetlands/erp/rules/stormwater/index.htm.

The Applicant's Handbook applies to the design of stormwater treatment systems authorized pursuant to Chapter 373, F.S. that do not serve agricultural or silvicultural activities. These Stormwater Treatment Systems include the following structural and non-structural BMPs:

- Retention Basin
- Exfiltration Trench
- Underground Storage and Retention Systems
- Underground Retention Vault/Chamber Systems
- Swales
- Vegetated Natural Buffers
- Pervious Pavement Systems
- Green Roof/Cistern System
- Wet Detention Systems
- Managed Aquatic Plant Systems (MAPS)
- Stormwater Harvesting
- Wetland Stormwater Treatment Trains
- Underdrain Filtration Systems
- Natural Area Conservation
- Site Reforestation
- Disconnecting DCIA
- Florida-Friendly Landscaping
- Rural Subdivisions

3.8 Low Impact Development Center

- The Low Impact Development Center (http://lowimpactdevelopment.org/index.htm) was established in 1998 to develop and provide information dedicated to research, development, and training for water resources and natural resource protection issues. The Center focuses on furthering the advancement of Low Impact Development technology.

3.9 Florida Water Star Program

Florida Water Star (http://floridawaterstar.com) is a water conservation certification program for developments. It was developed by St. John's River Water Management District in 2006 and became a statewide program in 2012. SFWMD works in conjunction with the Florida Water Star Program.

3.10 Data from Other Sources

Data collected from other sources was based on research of available web-data portals and ADA's own data catalogs. Data collected pertinent to LID management practices, flood protection targets, and design criteria from these sources were evaluated on a case-by-case basis to determine the relevance for the development of this LID Master Plan.

4.0 LOW IMPACT DEVELOPMENT SITE PLANNING

The traditional engineering approach to storm water management is to convey runoff away from the development site into man-made drainage structures designed to accommodate a large volume of stormwater. In contrast, Low Impact Development uses the natural, pre-development features of the site to maximize on-site infiltration, storage, and treatment of runoff while reducing the disruptive effects of urban runoff patterns. Benefits of implementing LID BMPs include:

- Maintain natural infiltration of stormwater
- Reduce the discharge of specific pollutants into local waterways
- Provide more aesthetically pleasing developments
- Reduce the flood impacts in the City stormwater system.
- Provide a wide range of economic and ecological benefits to the City and County through infrastructure savings
- Lower water management and treatment costs
- Promote potable water conservation
- Integration of water use and land use planning.

Revision. Implementation of the LID begins at the site planning level of the site development or redevelopment process. One of the first steps in site planning involves taking inventory of the existing features on the site including topography, soil characteristics, flow paths, drainage features, building and stormwater infrastructure, impervious areas, open spaces, and vegetation. Through LID techniques, developments are designed to be integrated with these existing features and to retain or simulate the pre-development site conditions.

LID design techniques include both structural and non-structural hydrologic controls that compliment traditional stormwater treatment and conveyance systems by utilizing pre-development hydrological features to decentralize and micromanage stormwater runoff at its source. Throughout the site development process, alternative design options that include LID techniques or LID techniques combined with traditional stormwater management infrastructure are evaluated and integrated into the site plan to the greatest extent possible. The overall LID site planning development process includes:

1. Identification and compliance with existing site planning regulations and ordinances,
2. Assessment and inventory of pre-development site conditions,
3. Development of the preliminary site plan,
4. Minimization of DCIA (Directly Connected Impervious Areas),
5. Evaluation and implementation of Integrated Management Practices, these are LID management techniques employed to achieve the desired post-development hydrologic condition,
6. Comparison of pre-development and post-development hydrology, and
7. Completion of LID Site Plan.

4.1 Non-Structural LID Site Planning Practices

When managed improperly, stormwater runoff contributes to water pollution, flooding, erosion, and groundwater recharge deficits. Implementation of LID techniques serve to manage stormwater runoff through the restoration and preservation of the natural drainage features present at the development site by applying runoff source control. The application of LID techniques throughout the site planning process reduces the use of traditional conveyance materials, such as steel and concrete, and often results in a more aesthetically pleasing site, lower development and maintenance costs and additional recreational resources. Nonstructural LID practices use native and natural features of the pre-development site to attenuate peak runoff and overall runoff volume. Implementation of nonstructural LID practices improve water quality and increase groundwater recharge within the development site.

The primary nonstructural LID site planning practices and considerations most applicable to the City of Doral are the following:

- Restoration and preservation of pre-development topography and soil profile
- Preservation and use of native and local vegetation
- Open space design and conservation
- Minimization of total impervious areas
- Reduction of DCIA

The following sections provide the purpose, implementation, and benefits of the above nonstructural LID concepts.

4.1.1 Preservation of Site Topography and Soil Profile

Traditional site development typically requires adding grading fill material to create new drainage contours and infrastructure foundations. The drainage contours are traditionally designed to direct drainage away from the site into a pipe network with an end-of-pipe treatment system. The topography of the site, including the natural slopes and depressions, define the natural flow path of stormwater runoff. With LID, the natural flow path is preserved and incorporated into the site plan as an existing open conveyance system where possible.

The soil profile includes the hydrologic soil groups, depth, extent, and infiltration capacity present throughout the site. The soil types present should be delineated within the site plan. Once delineated, the soil profiles should guide the placement of impervious areas, open or vegetated space, and stormwater management features. Locations of soil groups with low hydrologic function, such as clays and disturbed soils, are ideal for placement of buildings, parking areas, roadways, ponds, and other impervious structures. Areas with highly permeable soil groups are ideal for implementing LID stormwater management features relying on infiltration of runoff. Once the soil profiles have been established, construction activities must limit soil compaction in the areas of soils with higher permeability to protect the natural soil characteristics.

To better preserve the pre-development topography and native soil characteristics, instead of using traditional slab-on-grade construction for building foundations, which require alteration of the natural contours and soil conditions of the site, an alternative construction method should be used when possible. For example, constructing buildings using stem wall construction, or pier and beam for raised floor foundations instead of slab-on-grade. **Figure 4-1** provides an example of a type of pier and beam foundation. Both alternative construction methods create a crawlspace below the foundation and minimizes the amount of excavation required which dramatically limits disturbance of the pre-development site.

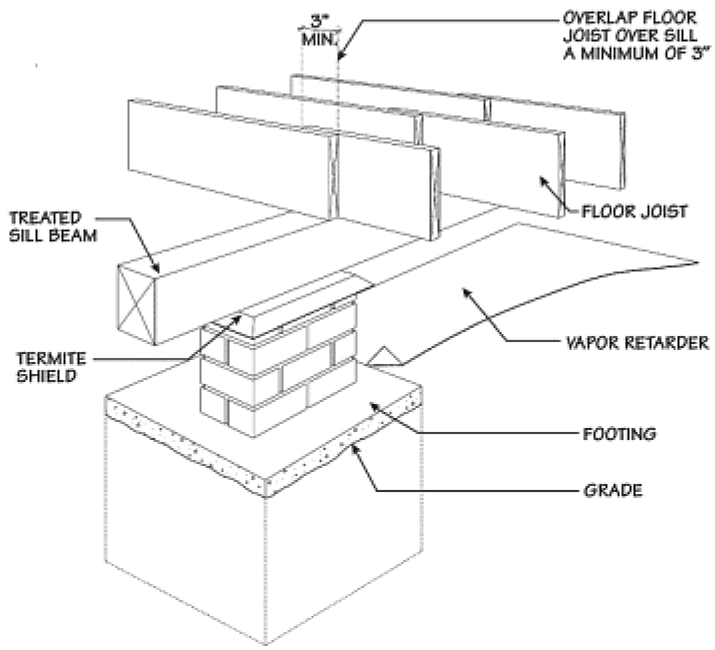

Figure 4-1 – Interior Detail of Example Pier

If the natural properties of the soil are modified during construction through compaction or other activities, soil amendment is recommended, and may be required. Soil amendment involves changing the soils chemical or physical properties through the addition of other materials, or through mechanical means such as tilling or aeration. As an LID practice, soil amendment is used to increase the infiltration capacity, storage capacity, or pollutant removal capacity of the soil, to add the nutrients needed for vegetation, and to stabilize sandy soils. For example, the addition of compost to compacted soils can increase the porosity and the permeability of the soil. It should be noted that soil amendment is not able to fully restore the natural characteristics of compacted soils. As such, the most effective way to preserve the soil profile is to limit construction activities, including vehicle and equipment travel, within areas identified to have highly permeable soils.

Additional preservation of site topography and soil profile LID practices include:

- Selective grading and clearing

- Minimize soil disturbance and compaction
- Soil Amendment
- Reduce construction on highly permeable soils
- Locate new buildings, parking, and ponds in areas that have lower hydrologic function, such as clayey or disturbed soil

4.1.2 Preservation and use of Native and Local Vegetation

The pre-development site inventory and assessment includes the vegetation present on the site. Both Florida native and exotic plant species should be inventoried and taken into account when designing the initial site plan with existing vegetation buffers around bodies of surface water preserved. Vegetation prevents erosion, reduces pollution levels, increases infiltration by decreasing runoff velocities, intercepts rainfall, and increases evapotranspiration rates. Traditional site development includes clearing onsite vegetation, which disturbs native soils, and introduces new vegetation that requires a greater amount of water and nutrients to become established compared to the pre-development vegetation present on the site. Preserving pre-development vegetation on the site and using Florida native vegetation creates a longer-lasting landscape and reduces the effort and cost of maintenance.

Through the use of hydrozones, plants are grouped into zones throughout the site based on nutrient demands and sunlight and water requirements. When designed and implemented, hydrozones minimize water, fertilizer, and pesticide use throughout the development. Whenever feasible, trees and native plants present on the site should be preserved and incorporated into the site design. The use of turfgrass should be limited to recreational areas, swales, and areas in need of erosion control that cannot be provided using other types of native ground cover.

When included in the site design, the type of turfgrass used should be specific to the environmental conditions of the planting area. The *Florida-Friendly Landscaping Guide to Plant Section & Landscape Design* provides landscape design strategies, planning worksheets, and a list of plants recommended within the four regions of Florida. The *Florida-Friendly Landscaping Pattern Book* provides sample plants and designs based on site conditions specific for USDA hardiness zones in South Florida. Both handbooks can be found at http://fyn.ifas.ufl.edu/. Vegetation types and species extracted from the *Florida-Friendly Landscaping Pattern Book* are provided in **Attachment D**. The tables provide specific examples of plants, flowers, and grass types recommended for South Florida, grouped by plant type, characteristics, and sun/shade requirements.

Preservation of native and local vegetation LID practices include:

- Preservation and incorporation of conservation areas and wetland habits
- Removal of exotic vegetation (recommended when greater than 5%)
- Retention of existing native vegetation
- Introducing native vegetation appropriate to existing site conditions
- Conservation of existing Tree Canopy

- Limit use of turfgrass and select turfgrass species with characteristics matching existing site conditions

4.1.3 Open Space Design and Conservation

Once the inventory and assessment of the site topography, soil profiles, and vegetation have been completed and delineated, the next step in the LID site plan is to design and outline the placement of open space and infrastructure such as roadways, sidewalks, lot layouts, buildings, driveways, and parking spaces. Open space includes existing or designed pervious areas, such as natural areas, recreational areas, common use areas, and buffer zones. When planning the layout of the site, employ the LID strategies of preserving the existing topography, soil zones with positive drainage benefits, and native plant communities by maximizing the area designed for open space. Larger open space areas and open spaces with smaller borders provide the maximum benefit for both stormwater management and wildlife.

Open spaces can be utilized for alternative LID stormwater management strategies that reduce the impact of the site development on the watershed. Open spaces maximize overland sheet flow with longer flow paths that reduce runoff velocities, increase residence times, and provide space for planting native vegetation. One method that maximizes the open space available is placing buildings with the cluster design approach. The cluster design approach increases the number of buildings or units per acre, which reduces overall infrastructure and development costs.

The Central Broward Water Control District requires a minimum of 25% open space for residential areas. In Alachua County the minimum required open space is 20% for residential and 50% for rural areas. It is recommended that the City of Doral adopt local zoning ordinances and building codes to include an open space requirement and to provide flexibility in the development design to encourage implementation of open space. Based on the conditions of the City and on common practices of other municipalities, it is recommended that 25% open space be required for new residential developments and for existing developments that are expanded or undergo substantial changes. A minimum requirement of 15% open space is recommended for commercial/industrial developments.

Additional open space design and conservation LID practices include:

- Increase (or augment) the amount of vegetation on the site.
- Maximize use of open swale systems
- Maximize overland sheet flow
- Avoid total site clearing
- Reduce fill and grade operations

4.1.4 Minimization of Total Impervious Areas

The greatest sources of impervious areas are the traffic distribution network and building rooftops. Alternative roadway layouts that implement shorter roadway lengths, such as the loops and lollipops layout, can reduce the overall roadway surface by 26% compared to implementation of the traditional grid layout. In some cases, the use of the T-shaped turn-about instead of the more common cul-de-sac design can decrease the roadway area needed, without adversely affecting the desired traffic access. Throughout the design of the traffic distribution network, pavement lengths and widths should be minimized to the extent that safety consideration allow.

When designing parking lots, use the smallest space dimensions with the fewest number of spaces, and use pervious areas for overflow parking needed for seasonal or rare events. Drainage from the impervious areas should be designed to direct runoff to vegetated, pervious areas such as swales or bioretention islands before entering a conventional pipe conveyance system.

Buildings should be designed to maximize the ratio of square footage to roof area. The application of high density development strategies will reduce the stormwater runoff per building and decrease the total impervious area compared to low-density developments with the same number of units. High-density development strategy also has less impact on the overall watershed and can improve the water quality of runoff generated on the site.

Additional minimization of total impervious areas LID practices include:

- Alternative roadway, sidewalk, parking lot, and driveway design standards to minimize imperviousness
- Minimize width and lengths of traffic distribution networks
- Implement pervious shoulders and right-of-way areas
- Limit the installation of sidewalks to one side of roadways

4.1.5 Reduction of Directly Connected Impervious Areas

Once the preliminary site plan has been developed which minimizes the total impervious area, preserves the sites natural hydrological characteristics and vegetation, and maximizes the areas of open space, the site plan should be evaluated to disconnect the unavoidable impervious areas. Stormwater runoff should be directed to flow into natural areas, vegetated buffer zones, and soils with favorable infiltration. The flow from large impervious areas should be broken up into smaller drainage areas with the flow directed to stabilized vegetated areas.

LID systems are composed of several incremental structural and nonstructural hydrologic controls. By disconnecting impervious areas from directly discharging into the offsite discharge system, the need for costly stormwater conveyance and treatment systems are reduced. Instead of large runoff volumes being drained into centralized basins and piped long distances to traditional end-of-pipe treatment facilities, runoff from individual roof tops is separated and treated using small basins located adjacent to the structure. Runoff from paved roads and parking areas are also separated using structural LID controls, and the flow paths are directed to vegetated areas located within and adjacent to the impervious area. By reducing DCIA, the negative impacts of a component failure have significantly less negative impact on the overall site and is often less costly to repair.

LID practices that reduce DCIA include:

- Direct drainage to stabilized vegetated areas.
- Site layout to break up flow directions from large paved surfaces
- Disconnect roof drains and drain to vegetated areas
- Site development to encourage sheet flow through vegetated areas (Locate impervious areas so that they drain to permeable areas)

4.2 Structural LID Practices and Stormwater Management

Structural LID practices use of a wide array of simple, cost-effective techniques that focus on site-level hydrologic control. LID projects should strive to obtain or improve the same hydrologic and hydraulic conditions that were present before development by maintaining runoff conveyance patterns, infiltration and treatment capacity, total stormwater runoff volume controls.

After completion of the preliminary site planning and minimization of DCIA, the next step in the LID Site Plan is evaluation and implementation of Integrated Management Practices (IMPs). IMPs are LID management techniques employed to achieve the desired post-development hydrologic condition. Ideally, LID IMPs technologies are located at the runoff source, on level ground, and within individual lots of the development. LID IMPs eliminate the need for a large centralized system to control the entire runoff of the development. Aside from the main characteristics of these low impact IMPs of providing quantity and quality control and enhancement, IMPs must provide:

- Groundwater recharge through infiltration or exfiltration into the soil.
- Retention or detention of runoff for permanent storage or for later release.
- Pollutant settling and entrapment by conveying runoff slowly through vegetated swales and natural buffer strips.
- Aesthetic value to the property which enhances a sense of community lifestyle.
- Satisfaction of local government requirements for green or vegetated buffer space by implementing multiple landscaped areas within each lot.

The most effective type of design for maximum on-lot stormwater runoff control consists of placing source controls in series, this is especially effective at reducing volume and peak flow rates. **Attachment E** provides an overview and comparison matrix of the most common LID IMPs utilized in South Florida which have the greatest applicability for the City of Doral. The matrix in **Attachment E** includes the advantages, disadvantages, space requirements, maintenance frequency and approximate cost extent, and proximity to building foundation.

The primary structural LID BMPs and practices that appear to be most applicable to the City of Doral include the following:

- Bioretention Basins or Rain Gardens
- Tree Box Filters or Infiltration Planters
- Vegetated Swales
- Filter Strips or Vegetated Buffers
- Infiltration Trench
- Exfiltration Trench or French Drains
- Green Roofs/Rain Barrels or Cisterns
- Permeable Pavement
- Detention Ponds
- Parking Chambers

4.2.1 Bioretention Basins or Rain Gardens

Bioretention basins are small landscaped basins, on-lot, which hold and infiltrate stormwater. These are intended to manage and provide water quality treatment by using a conditioned planting soil bed and materials to filter the stored runoff. It is recommended that landscaped areas only use native species (see **Attachment D** for recommended species) to promote water conservation, benefits to native wildlife, aesthetic benefits to neighborhoods, and increase in property values. The major components of Bioretention Basins or Rain Gardens systems include:

- Pretreatment area (optional – required for significant volumes)
- Ponding area
- Ground cover layer
- Plant Material and planting soil
- In situ soil
- Inlet and outlet controls
- Maintenance

This approach is very flexible as a method of runoff source control for stormwater in residential developments, parking lot islands, and landscaped areas in commercial or public areas. In cases where soil permeability does not benefit infiltration, underdrains can carry the filtered water downstream through the Bioretention basin. An example of a typical Bioretention basin is shown in **Figure 4-2**.

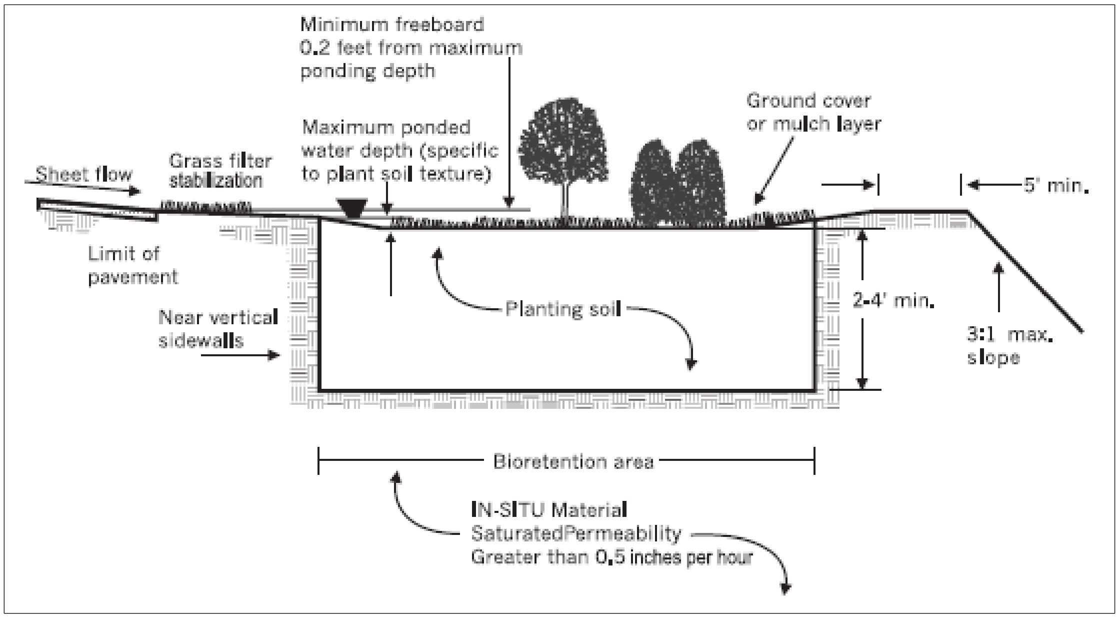

Figure 4-2 – Typical Bioretention Basin Cross-section

A summary of design considerations for evaluating the suitability of Bioretention basins or Rain Gardens are summarized in **Table 4-1**.

Table 4-1 – Bioretention Basins and Rain Garden Design Considerations

Parameter	**Consideration**
Treatment Area	Individual lots in subdivisions or common areas, other landscaped areas and retrofit projects. Minimum surface area of 50 – 200 sq. ft. Minimum length to width ratio 2:1.
Pretreatment Area	Required when significant volume is anticipated from parking lots and commercial areas (i.e. grass buffer strip or vegetated swale).
Proximity to building Foundation	Minimum distance of 10 feet down gradient.
Soils	Infiltration rates < 0.1 in/hr require underdrains or soil augmentation.
Topography	May be difficult in areas with slopes > 10%.
Depth of Water Table	Not suitable if difference between seasonal high water table and bottom of Bioretention area is < 2 feet.
Groundcover Area	3 inches of mature mulch recommended.
Planting Soil	Depth = 4 feet / Clay content ≤ 10%. Soil mixture to include sand, loamy sand, and sandy loam.
Inlet and outlet control	Non-erosive flow velocities (0.5 ft/sec)
Plant Material	Minimum 3 native species. (see **Attachment D**)
Maintenance	Routine landscape – 5-7% of construction cost. Mulch should be replaced annually. Ornamental rocks such as lava rock can reduce maintenance cost of rock

	Accumulated trash and sediment must be cleaned out. Infiltration capacity must be inspected (Total drawdown time 72-hr).
Hydrologic Design	Determine by State or Local agency

4.2.2 Tree Box Filters or Infiltration Planters

Tree box filters or infiltration planters are a small scale variation of Bioretention basins. As the name implies, tree boxes use trees and infiltration planters use plants other than trees. The two basic types are: 1) a filter, or 2) detention boxes. The box performs as a filter if the bottom is open and stormwater is discharged through infiltration or the box acts as a detention box when the bottom is closed. In the detention box, the filtered stormwater flows into an underdrain and is discharged to another LID BMP or pipe system. Each consists of a ponding area or container filled with a layer of mulch, planting soil, and plants or trees.

As with bioretention basins, native species of trees and plants should be used (see **Attachment D**) to promote water conservation, provide benefits to the native habitat, add aesthetic value to the site, and reduce the heat island effect. Plants reduce the volume of runoff and can enhance the quality of discharge or infiltrated water by amending the soil to assist in removing a particular pollutant present in the area. They are appropriate for new projects and can be retrofitted into existing stormwater systems. An example of a typical Tree Box Filter is shown in **Figure 4-3**.

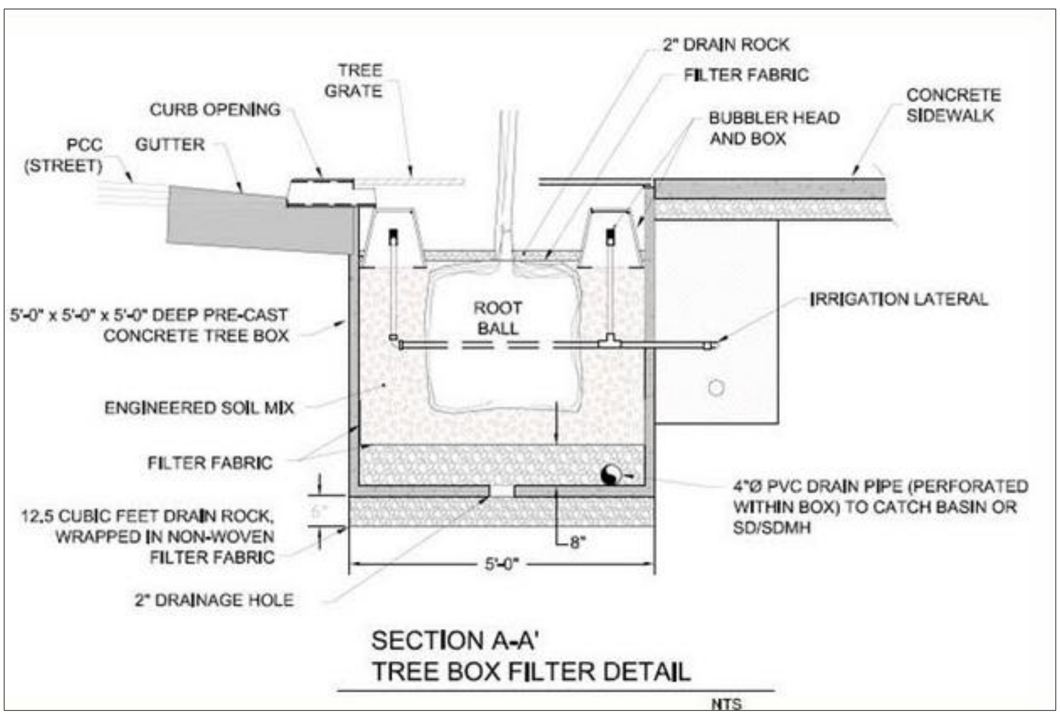

Figure 4-3 – Typical Tree Box Filter

A summary of design considerations for evaluating the suitability of Tree Box Filters and Infiltration Planters are summarized in **Table 4-2**.

Table 4-2 – Design Considerations for Tree Box Filters and Infiltration Planters

Parameter	Consideration
Treatment Area	New Developments or retrofit into existing stormwater systems
Pretreatment Area	N/A
Proximity to building Foundation	Minimum distance of 10 feet down gradient if infiltration permitted. If located closer boxes should be contained with impermeable structures & with an underdrain.
Soils	Reduction of soil will directly impact the potential size of the tree. Avoid soil compaction. 12-inch drainage rock depth under the soil with a 2-inch minimum depth of drainage rock above drainage hole
Topography	N/A
Depth of Water Table	N/A
Groundcover Area	Bark mulch should be placed 4 inches deep. Pea gravel should be placed 2 inches deep.
Planting Soil	Typically amended to facilitate vigorous plant growth and not restrict performance requirements. Organic matter improves moisture retention and microbial action.
Inlet and outlet control	Curb cuts may be used as entry points of runoff Grating (surrounding pavement is graded towards box).
Plant Type and Species	See **Attachment D**.
Maintenance	Routine landscape. Maintaining the health of the plants, pruning and addition of mulch semi-annually. Trash and debris removal may be required based on location. If plant material dies, it must be replaced as part of regular maintenance.
Hydrologic Design	Determine by State or Local agency

4.2.3 Vegetated Swales

Vegetated swales are commonly used to transport stormwater runoff away from roadways and right-of-way areas. Swales reduce or eliminate the need for standard curb and gutter and pipe systems. Swales optimize stormwater drainage systems by reducing stormwater runoff, and provide many benefits including attenuation of peak flow rates and runoff velocities. Vegetated swales are classified as either dry or wet.

Dry swales provide water quantity and water quality control by facilitating stormwater infiltration of all or a portion of design treatment volumes. Wet Swales use residence time and natural growth to reduce peak discharge and provide water quality treatment before discharge to another LID BMP or pipe system. Permeability of the soil determines whether a dry swale or wet swale is used. An example of a Vegetated Conveyance Swale is shown in **Figure 4-4**.

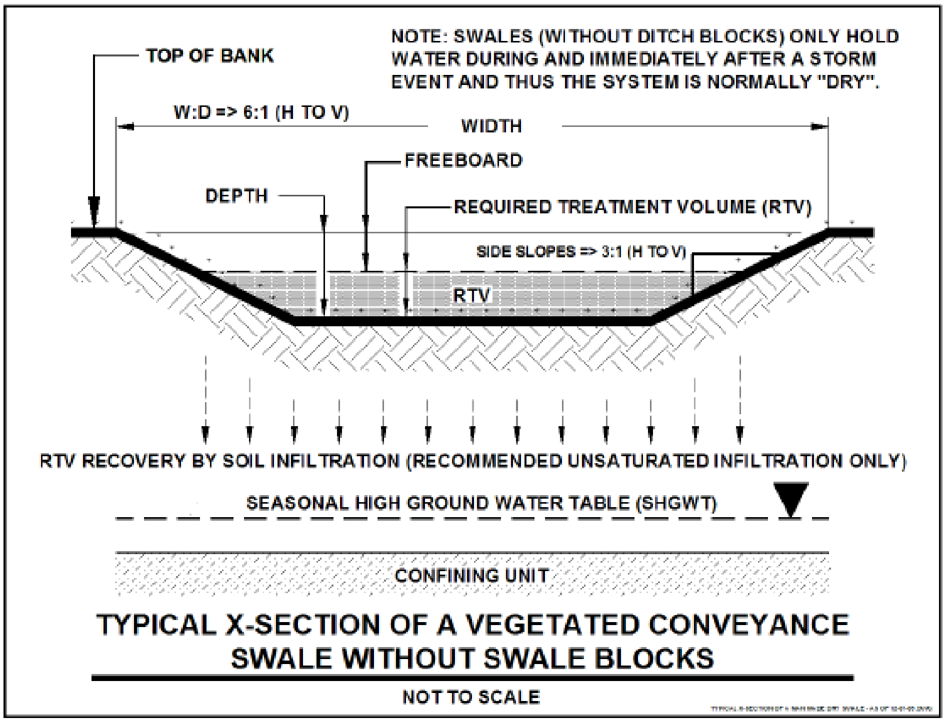

Figure 4-4 – Typical Cross-section of a Vegetated Conveyance Swale without Swale Blocks

A summary of design considerations for evaluating the suitability of Vegetated Swales are summarized in **Table 4-3**.

Table 4-3 – Design Considerations for Vegetated Swales

Parameter	Consideration
Treatment Area	Along roadways and right-of-way areas. Linear retention swales or conveyance swales. Top width to depth ratio of cross section ≥ to 6:1 or side slopes ≤ to 3H:1V
Pretreatment Area	N/A
Proximity to building Foundation	Minimum distance of 10 feet down gradient.
Soils	Permeability will determine whether dry or wet swale can be used. The minimum infiltration rate through the vegetation and soil shall be at least 1 inch per hour. Avoid soil compaction.
Topography	Trapezoidal or parabolic shape recommended
Depth of Water Table	Bottom of swale must be at least 2 feet above seasonal high water table.
Groundcover Area	Design to account for soil erosion potential, soil percolation, slope, slope length, and drainage area to prevent erosion and reduce pollutant concentration.
Planting Soil	Typically planted or has stabilized vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake.

Parameter	Consideration
Inlet and outlet control	Curb elimination, curb cuts, or curb replacements with raised knobs allow rainwater to enter vegetated swales.
Plant Material	See **Attachment D**.
Maintenance	Routine landscape. Inspected and maintaining to preserve adequate infiltration capacity in the soil. Trash and debris removal may be required based on location. Can become clogged with sediment deposits, overgrowth of alga, or overloading of oil and grease. Inspections should look for healthy vegetated slopes, erosion problems, blockage of flow path or any other damage.
Hydrologic Design	Determine by State or Local agency

4.2.4 Filter Strips or Vegetated Buffers

Filter strips or vegetated buffers are constructed or naturally occurring vegetated zones between pollutant sources and downstream receiving water bodies. The strips or buffers slow runoff, reduce peak discharge, allow for infiltration, and reduce stormwater volume. These types of structural LID practices should be used as a component of a broader management system and are not intended to be the sole stormwater treatment system in residential areas. In some instances, they are recommended for treatment of runoff from backyards of residential developments.

Vegetated buffers are typically composed of undisturbed native vegetation. If planted, only a diverse variety of native species should be used (See **Attachment D**). An example of a Vegetated Buffer is shown in **Figure 4-5**.

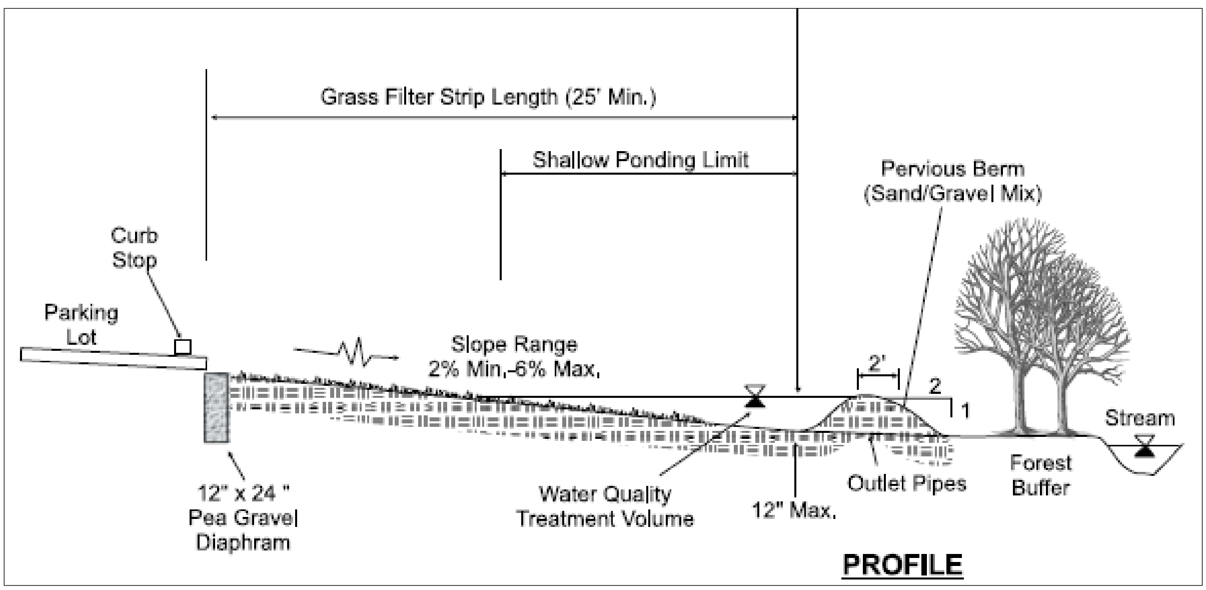

Figure 4-5 – Typical Profile of a Filter Strip

A summary of design considerations for evaluating the suitability of Vegetated Buffers or Filter Strips are summarized in **Table 4-4**.

Table 4-4 – Design Parameters for Vegetated Buffers and Filter Strips

Parameter	Consideration
Treatment Area	Closed growing vegetation (natural or planted). Between pollutant source and downstream receiving water body. Sensitive areas (waterbodies, wetlands, erodible soils). Runoff from backyards of residential developments. Minimum dimensions recommended are 25 feet and maximum is 100 feet parallel to flow direction. The length perpendicular to the runoff must be at least as long as the contributing runoff area.
Pretreatment Area	Should be used as a part of a treatment train to reduce stormwater volume and pollutant
Proximity to building Foundation	Natural areas adjacent to rear-lots that have good infiltration potential.
Soils	The minimum infiltration rate through the vegetation and soil shall be at least 1 inch per hour.
Topography	Maximum slope shall not be greater than 6:1
Depth of Water Table	Seasonal high groundwater table shall be at least two feet below the bottom of the vegetated natural buffer. Unless appropriate design demonstrates is suitable for the specific site conditions.
Groundcover Area	Design to account for soil erosion potential, soil percolation, slope, slope length, and drainage area to prevent erosion and reduce pollutant concentration.
Planting Soil	Undisturbed native species, if planted See **Attachment D.**
Inlet and outlet control	Erosion control measures should be used to prevent erosion and sedimentation.
Plant Type and Species	Undisturbed native vegetation, if planted See **Attachment D.**
Maintenance	Inspection of sheetflow and infiltration of the required treatment, generally 24 to 72 hours after a storm. Must be inspected annually. Check damage by foot or vehicular traffic or encroachment by adjacent property owners. Inspect health and density of vegetation. Routine landscape if needed.
Hydrologic Design	Determine by State or Local agency

4.2.5 Infiltration Trench

Infiltration trenches consist of shallow excavated areas filled with rock material to create a subsurface reservoir layer. They store stormwater runoff until it can be infiltrated into the surrounding soil over a period of 72 hours. They are very adaptable making them ideal for small urban drainage areas. When filter strips and grassed swales are used in combination as a form of pretreatment, infiltration trenches area highly effective at removing all targeted pollutants from stormwater runoff.

Concerns of over groundwater contamination, soil permeability, and clogging at the site inflict restrictions on the use of infiltration trenches. Examples of conditions where infiltration trenches may not be appropriate to use include:

- Sites with low soil permeability
- Industrial locations where contaminated or toxic spills may occur
- Sites with unstable soils
- High groundwater table
- Sites with contaminated groundwater
- Excessively permeable soils as pollutants may affect groundwater quality
- Terrain with steep slopes

To prevent infiltration trenches from becoming plugged over time, sediment must be removed before stormwater enters the trench. It is important to consider other forms of pretreatment such as vegetated filter strips or grassed swales to remove and filter sediment upstream of the infiltration trench. Refer to **Attachment D** for suitable, native vegetation types to use. An example of an Infiltration Trench is shown in **Figure 4-6**.

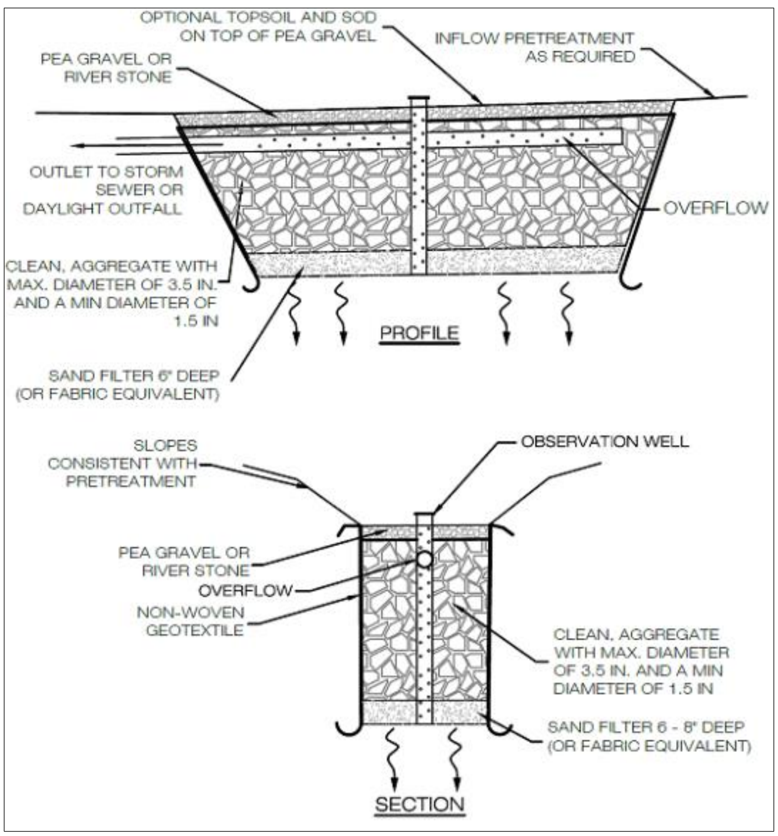

Figure 4-6 - Typical Profile & Section View of an infiltration Trench

A summary of design considerations for evaluating the suitability of Infiltration Trenches is provided in **Table 4-5**.

Table 4-5 – Design Parameters for Infiltration Trenches

Parameter	Consideration
Treatment Area	Small urban areas. Parking lots, recreational areas. Minimum surface area range: 8 – 20 sq.ft Minimum length to width ratio: 2:1
Pretreatment Area	Other form of pretreatment is ideal. Vegetated filter strips or grassed swales.
Proximity to building Foundation	Minimum distance of 10 feet down gradient.
Soils	The minimum infiltration rate through the vegetation and soil shall be at least 1 inch per hour.
Topography	May be difficult in areas with steep slopes
Depth of Water Table	Not suitable if difference between seasonal high water table and bottom of Trench area is < 2 ft
Backfill	Clean aggregate > 1 ½”, <3”, surrounded by engineering filter fabric
Planting Soil	Pretreatment
Inlet and outlet control	Non-erosive flow velocities (0.5 ft/sec). Overflow system must be identified.
Plant Material	Pretreatment native species. (see **Attachment D**)
Maintenance	Periodic monitoring Accumulated trash and sediment must be cleaned out. Infiltration capacity must be inspected (Total drawdown time 72-hr).
Hydrologic Design	Determine by State or Local agency

4.2.6 Exfiltration Trenches or French Drain

Exfiltration trenches, or French drains are the most commonly used stormwater system in South Florida. These systems consist of at least one catch basin or inlet that leads to a perforated or slotted pipe contained in a bed of aggregate filter media. They can be placed below paved surfaces or at the bottom of retention areas and discharge to the surrounding native soils. Advantages of exfiltration trench systems include:

Advantages:

- Requires relatively low construction cost
- Occupies relatively minimal ground space
- Provides pollutant and sediment treatment

Disadvantages:

- Requires periodic cleaning and maintenance
- Not for use in areas of contamination
- Requires permeable soils
- Debris and sediment may clog perforated pipe

Figure 4-7 shows a typical longitudinal profile and cross section of an exfiltration trench. The effectiveness of exfiltration trenches is dependent on the soil hydraulic conductivity, groundwater table elevations, and available topographic elevations. Exfiltration trenches are deemed viable when soil hydraulic conductivity is greater than $1x10^{-5}$ cfs/ft^2/ft of hydraulic head and the average October elevation in Miami Dade County is at least one to two feet below the control elevation.

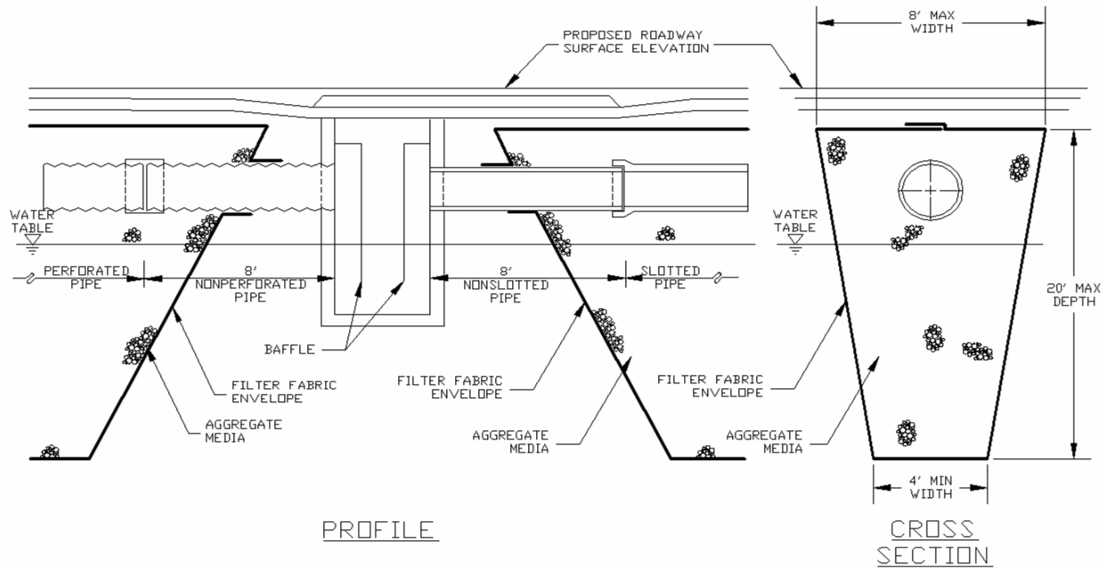

Figure 4-7 - Typical Exfiltration Trench

A summary of design considerations for evaluating the suitability of Infiltration Trenches are summarized in **Table 4-6**.

Table 4-6 – Design Parameters for Exfiltration Trenches (French Drains)

Parameter	Consideration
Treatment Area	Urban areas with limited surface space available, parking lots, recreational areas.
Pretreatment Area	Other form of pretreatment is ideal. Vegetated filter strips or grassed swales.
Proximity to building Foundation	Minimum distance of 10 feet down gradient.
Soils	Minimum soil hydraulic conductivity of $1x10^{-5}$ cfs/ft^2/ft
Topography	May be difficult in areas with steep slopes
Depth of Water Table	Pipe invert should be at or above the water table whenever possible
Backfill	No. 57 Stone ¾"-1", surrounded by engineering filter fabric
Inlet and outlet control	Control elevation determined by groundwater table, or lowest pipe inlet elevation. May be a self-contained system. If not self-contained, weir or control structure required.
Maintenance	Periodic monitoring

Parameter	Consideration
	Accumulated trash and sediment must be cleaned out. Baffles are not required, but recommended to prevent clogging the perforated pipe.
Hydrologic Design	Determine by State or Local agency

4.2.7 Green Roofs or Rain Barrels/Cisterns

Green roofs and rain barrels are roof water management devices that collect stormwater and provide retention storage volume above-ground and underground. The runoff collected can later be used for non-potable activities including irrigation, toilet flushing, or industrial processes. The most common above-ground systems are rain barrels which are low-cost, effective, and easily maintained. Underground systems are composed of a pipe to divert runoff to the cistern, an overflow system for when the cistern is full, and a pump and a distribution system to transport the non-potable water for the intended use.

Rain barrels and cisterns also provide an opportunity for water conservation and a reduction in water utility costs. An example of a rain barrel and cistern system is shown in **Figure 4-8**.

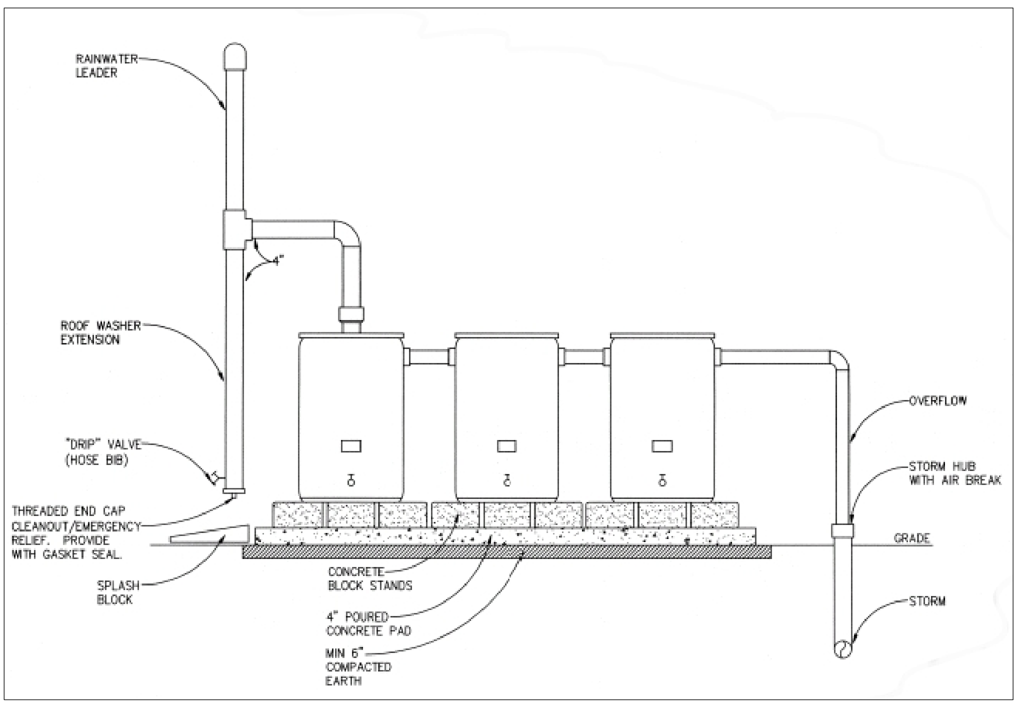

Figure 4-8 - Typical Profile of a Rain Barrel System

A summary of design considerations for evaluating the suitability of Rain Barrels and Cisterns are summarized in **Table 4-7**.

Table 4-7 – Design Considerations for Rain Barrels and Cisterns

Parameter	Consideration
Treatment Area	Rooftops and other small impervious areas. Size of Rain Barrels is a function of rooftop surface area & the inches of rainfall to be stored. Premanufactured residential cisterns come in sizes ranging from 100 to 1,400 gallons.
Pretreatment Area	Filter screens should be used on gutters to prevent clogging of debris.
Proximity to building Foundation	Beneath each downspout.
Soils	N/A
Topography	N/A
Depth of Water Table	N/A
Groundcover Area	N/A
Planting Soil	N/A
Inlet and outlet control	Downspout & gutters.
Plant Material	N/A
Maintenance	Should be located for easy maintenance & replacement. Inspect and repair/replace treatment area components.
Hydrologic Design	Determine by State or Local agency

4.2.8 Permeable Pavement

Permeable pavement, unlike traditional pavements that are impermeable, allow water to pass through reducing the volume and peak of stormwater runoff. Some types can mitigate pollutants by allowing stormwater to percolate through the pavement and enter the soil below. Permeable surfaces include modular paving systems (concrete pavers, modular grass or gravel grids) or poured-in-place pavement (porous concrete, permeable asphalt). They work best on flat surfaces or with gentle slopes. Recent studies on the design, longevity and infiltration characteristics of pervious pavement systems are available on the University of Central Florida's website http://stormwater.ucf.edu/

Pervious pavement systems are retention system that should be used as part of a treatment train to reduce stormwater volume and pollutant load from parking lots and similar areas. One of the major advantage of using these type of systems is that it reduces impervious areas and increases usable land/developable space. The treatment efficiency is based on the amount of the annual runoff volume infiltrated, which depends on the available storage volume within the pavement system, the soil permeability, and the ability of the system to readily recover this volume. Ideal locations are parking lots, driveways, sidewalks and areas with light traffic (<100 cars/day). An example of a pervious pavement system is shown in **Figure 4-9**.

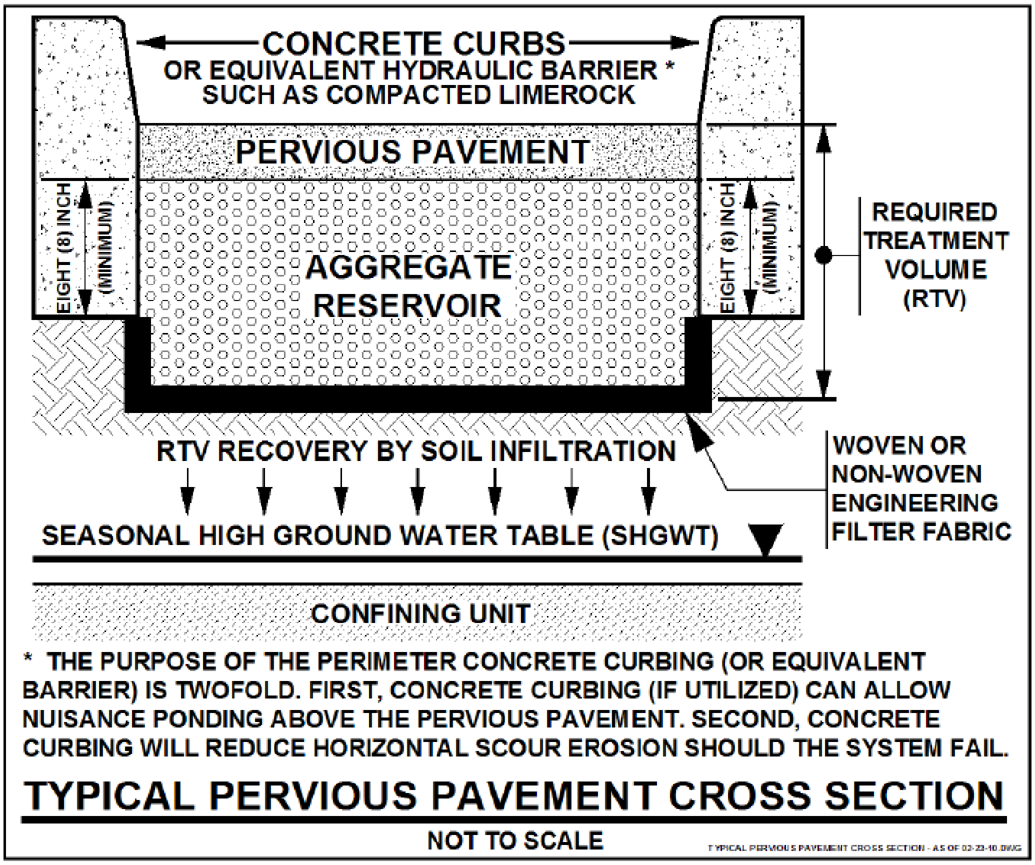

Figure 4-9 - Typical Pervious Pavement Cross-section

A summary of design considerations for evaluating the suitability of implementing pervious pavement is summarized in **Table 4-8**.

Table 4-8 – Pervious Pavement Design Considerations

Parameter	Consideration
Treatment Area	Parking lots, driveways, sidewalks and areas with light traffic. Avoid areas with high potential for hazardous material spills. Should consider potential for tripping hazards in areas used by pedestrians.
Pretreatment Area	Should be used as a part of a treatment train to reduce stormwater volume and pollutant
Proximity to building Foundation	Distance to foundation >10’ down-gradient and >100’ up-gradient without liner, septic systems, >100’ from water supply wells
Soils	Permeability rate >0.5 inch/hr
Topography	May be difficult in areas with steep slopes. Should not exceed 1.04%.
Depth of Water Table	Present challenges in shallow seasonal high groundwater tables and shallow confining units, >3’ recommended, if impermeable liner present >1’ recommended
Groundcover Area	Pervious surface.

Parameter	Consideration
Planting Soil	Pervious walks and bicycle paths must be placed over native upland soils or clean fill. For redevelopments, must be placed over rehabilitated soils.
Inlet and outlet control	Except for pervious walks and bike paths, curbing, edge constraint or other equivalent hydraulic barrier will be required to a minimum depth of 8 inches beneath the bottom of the pavement to prevent scouring from horizontal movement of water.
Plant Material	Native species. (see **Attachment D**)
Maintenance	Periodic vacuum sweeping is recommended annually and whenever the vertical hydraulic conductivity is less than 2.0 inches per hour or less than the permitted design percolation rate. Repair near edge constrains or overflows, and assure contributing area is stabilized and not a source of sediments.
Hydrologic Design	Determine by State or Local agency

4.2.9 Detention Ponds

Dry detention ponds detain a portion of urban runoff for a short period of time (24-hours after a storm) using a fixed opening to regulate outflow at a specified rate and allowing solids and associated pollutants time to settle out. Dry detention volume shall be provided equal to 75% of the amounts computed for wet detention. These systems in general are effective in removing total suspended solids but have low treatment efficiency for nutrients. They are normally dry between storm events. Sitting requirements call for a minimum of one foot from control elevation to the bottom of the detention zone. Therefore, constructing dry detention ponds on wetlands and floodplains should be avoided. Where drainage areas are greater than 250 acres and ponds are being considered, inundation of upstream channels may be of concern.

Wet detention ponds are designed to maintain a permanent pool of water and temporarily store urban runoff until it is released at a controlled rate. Hydraulic holding times are relatively short, such as hours or days. These systems are more efficient in removing soluble pollutants (nutrients) than dry detention due to the biological activity in the vegetation and water column. Enhanced designs include a forebay to trap incoming sediment where it can be easily removed. A littoral zone can also be established around the perimeter of the pond. SFWMD requires 20% Littoral Zone by area or 2.5% of the total basin area drainage to the pond, whichever is less.

For wet detention systems, the bleed-down volume is defined between the elevation of the overflow weir and control elevation and shall be the first one inch of runoff from the contributing area, or the total runoff of 2.5 inches' times the percentage of imperviousness, whichever is greater. The control elevation is the normal water level for the pond and it is established at the higher elevation of either the normal wet season tailwater elevation or the seasonal high groundwater table minus six inches. The maximum stage above the control elevation for providing bleed-down volume shall not exceed 18 inches unless alternative design is appropriate for the specific site conditions.

The permanent pool size shall be sized to provide a resident time that achieves the required nutrient removal efficiency. Resident time shall be based upon annual rainfall volumes. Maximum depth shall be no greater than 12 feet. The maximum allowable permanent pool depth as it relates to the aerobic zone is directly related to the anticipated algal productivity within the pond.

To ensure proper drainage, aerobic functioning and aeration, and regular vegetative health inspections are needed. Also, regular maintenance should be performed to remove sediment, trash and debris. Ideal locations of wet detention ponds include downstream of catchment and runoff, usually constructed at the lowest point of the site.

An example of a typical wet detention system cross section is shown in **Figure 4-10**.

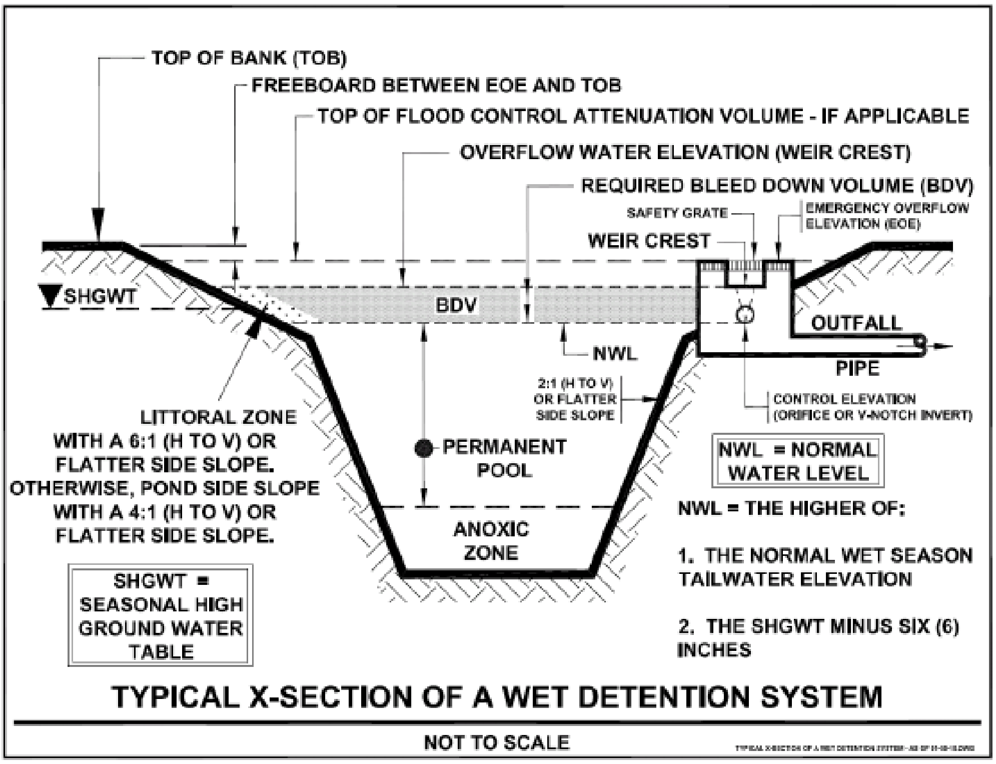

Figure 4-10 - Typical Cross-section of a Wet Detention System

A summary of design considerations for evaluating the suitability of implementing a wet detention system is summarized in **Table 4-9**.

Table 4-9 – Detention System Design Considerations

Parameter	Consideration
Treatment Area	Detention ponds are designed to slowly release a portion of the collected stormwater runoff through an outlet structure. Most significant component is the storage capacity of the permanent pool.

Parameter	Consideration
Pretreatment Area	Provide removal of both dissolved and suspended pollutants by taking advantage of physical, chemical, and biological processes. Can be implemented also as a part of a BMP treatment train.
Proximity to building Foundation	Distance to foundation >10’, septic systems >20’, public roadway >15’, drinking water wells >100’ is recommended
Soils	Can be used with almost all soil types. If soil permeability >2.5 in/hr, full treatment prior to the pond is recommended.
Topography	Pond slopes shall be restricted from public access or have slopes that are no steeper than 4:1. Deeper areas of the pond must maintain side slopes no steeper than 2:1.
Depth of Water Table	Moderate to high water table condition
Groundcover Area	Side slopes shall be stabilized by vegetation or other materials to minimize erosion and sedimentation of the pond.
Planting Soil	Managed Aquatic Plant Systems (MAPS) are aquatic plant-based BMPs. Littoral Zones shall be gently slopes (6:1) or flatter. 20% Littoral Zone by area or 2.5% of the total basin area drainage to the pond, whichever is less. Pond level shall be below 18 inches above control elevation to ensure vegetation can survive. Planting is recommended to meet 80% coverage requirement (MAPS) with no more than 10% consisting of exotic or nuisance species.
Inlet and outlet control	Outlet structure generally includes a drawdown device (orifice, “V” or square notch weir) set to establish a normal water control elevation and slowly release the bleed down volume.
Plant Material	Native species. (see **Attachment D**)
Maintenance	Ensure proper drainage, aerobic functioning and aeration. Vegetative regular inspections are needed to prevent erosion of side slopes and around inflow and outflow structures. Remove sediment, trash and debris. Inspect for potential mosquito breeding problems. Inspect littoral zone to assure invasive vegetation is not becoming established.
Hydrologic Design	Determine by State or Local agency

Design of wet detention ponds with various BMP features can improve their water quality benefits. Two BMPs that could add water quality benefit to wet retention ponds are floating wetlands and enhanced stormwater ponds. Details about the pond enhancements are explained below.

Floating Wetlands

Floating wetlands consist of aquatic plants attached to floating mats or other support material[19]. The biological processes related to the root systems of the plants utilize dissolved nutrients from the water, and thus work to remove dissolve nutrients in ponds. **Figure 4-11** shows an example of a floating wetland BMP implementation.

Figure 4-11 – Floating Wetland Mat[19]

Enhanced Stormwater Ponds

Enhanced stormwater ponds are wet ponds that are more elaborate than simple rectangular wet ponds with grassy slopes. Features of enhanced stormwater ponds enhance the abilities of the pond to have greater sedimentation and pollutant removal capabilities. Features such as shoreline vegetation, a spectrum of depths, and sedimentation forebays create treatment trains that have greater hydrologic benefits than standard treatment ponds. **Figure 4-12** shows a rendering of an enhanced stormwater pond.

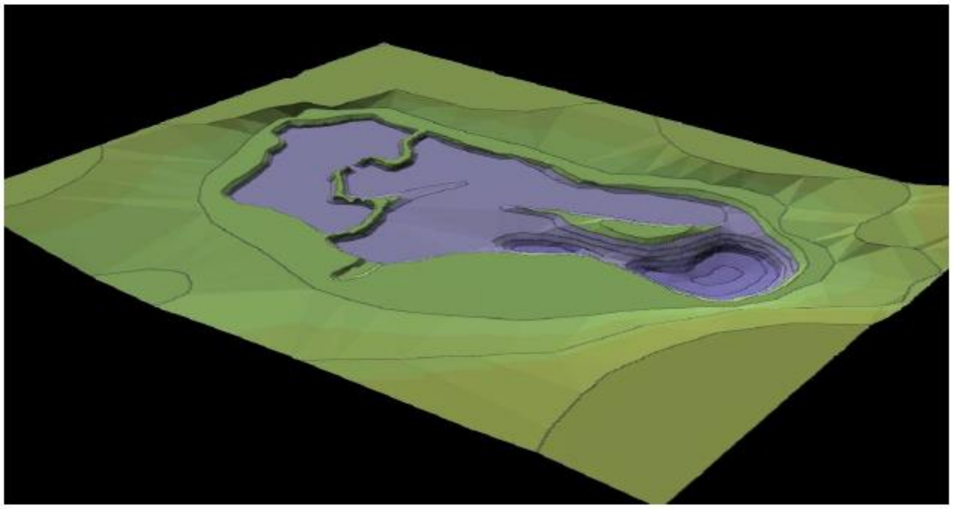

Figure 4-12 – Rendering of Enhanced Stormwater Pond[19]

4.2.10 Retention Ponds

Retention systems rely on absorption of runoff to treat urban runoff discharges. Water is percolated through soils, where filtration and biological action remove pollutants. Systems that rely on soil absorption require a deep layer of permeable soils at separation distances of at least 1 foot between the bottom of the structure and seasonal groundwater levels. Retention volumes shall provide equal to 50% of the above amounts computed for wet detention systems. Using retention systems in a watershed will help preserve or restore predevelopment hydrology, increase dry weather base flow, and reduce bank fill flooding frequency. Where groundwater requires protection, retention systems may not be appropriate.

Dry retention basins are depressed areas where incoming urban runoff is temporarily stored until it gradually filtrates into the surrounding soil. These would gradually drain down to maintain aerobic conditions that favor bacteria which aid in pollutant removal and to ensure the basin is ready to receive the next storm. Runoff entering the basin is sometimes pretreated to remove coarse sediment that may clog the surface soil pore on the basin floor. Concentrated runoff should flow through a sediment trap, or a vegetated filter strip may be used for sheet flow.

The required treatment volume to achieve the necessary efficiency shall be determined based on the percentage DCIA and the weighted curve number for non-DCIA areas. To avoid degradation of retention basin infiltration capacity specific construction practices should be implemented these include:

- Prevent unnecessary vehicular traffic to avoid soil compaction
- Excavation shall be done by lightweight equipment to minimize soil compaction
- Entire basin bottom must be deep raked and loosened for optimal infiltration once the basin has been excavated to final grade

Maintenance for regular trash and intermittent sediment removal should be performed, pollutants accumulate in soil and may require amendments and to be clean out. Ideal locations include downstream of catchment and runoff, and upstream from off-site stormwater management systems.

An example of a typical dry retention system cross section is shown in **Figure 4-13**.

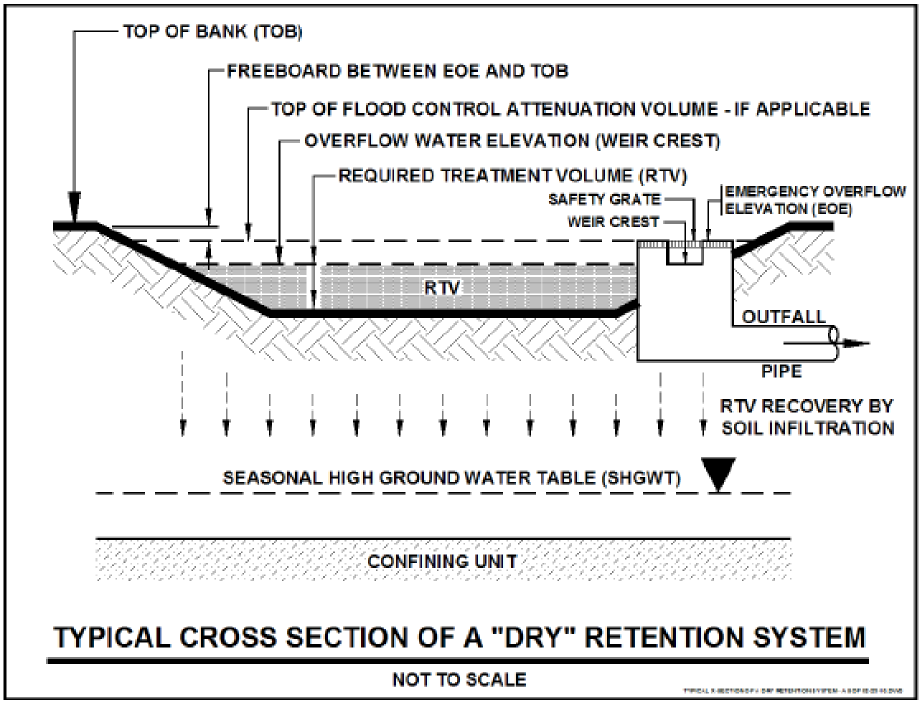

Figure 4-13 – Typical Cross-section of a Dry Retention System

A summary of design considerations for evaluating the suitability of implementing a dry retention system is summarized in **Table 4-10**.

Table 4-10 – Retention System Design Considerations

Parameter	Consideration
Treatment Area	Must have the capacity to retain required treatment volume without a discharge and without considering soil storage. Constructed or natural depression areas, typically flat with turf, natural ground cover or other appropriate vegetation to promote infiltration and stabilize basin slopes. Side slopes of 1:4 are recommended. Bottom slopes of 2% or zero are recommended to maximize infiltration.
Pretreatment Area	Stormwater pollutants such as suspended solilds, oxygen demanding materials, heavy metals, bacteria, some varieties of pesticides, and nutrients are removed as runoff percolates through the soil profile.
Proximity to building Foundation	Distance needs to be determined onsite prior to construction to prevent any adverse effects to building foundations, septic systems, or wells. Shall not be constructed within 50 feet of public or private potable water supply well.
Soils	Turf, natural ground cover or other appropriate vegetation.
Topography	Typically flat
Depth of Water Table	Seasonal high ground water table shall be at least 1 foot beneath the bottom of the retention basin.

Parameter	Consideration
	Unless alternative design is appropriate for the specific site condition.
Groundcover Area	Sides and bottom shall be stabilized with permanent vegetative cover, or pervious material to prevent erosion and sedimentation.
Planting Soil	Vegetation roots help maintain soil permeability. Grass needs to be mowed and grass clippings removed to reduce internal nutrient loadings.
Inlet and outlet control	Non-erosive velocities should be maintained to avoid resuspension of settled out solids.
Plant Material	Native species. (see **Attachment D**)
Maintenance	Remove accumulated sediments from retention basin bottom and inflow and outflow pipes. Remove trash and debris, trash racks and other components to prevent flooding and impeding flow. Maintain healthy vegetative cover to prevent erosion in the basin bottom, side slopes or around inflow and outflow structures.
Hydrologic Design	Determine by State or Local agency

Design of wet retention ponds with various BMP features can improve their water quality benefits. Two BMPs that could add water quality benefit to wet retention ponds are floating wetlands and enhanced stormwater ponds. Details about the pond enhancements are explained in **Section 4.2.9** above.

4.2.11 Parking Stormwater Chambers

Parking stormwater chambers are underground retention or detention systems. The stormwater chambers consist of underground pipes, vaults, or other water storage structure that captures stormwater runoff from an inlet or catch basin. The system is designed to retain stormwater runoff throughout the storm event or infiltrates the surrounding soil. In the case of non-perforated structures, after the storm event, the stormwater is released through an outlet structure that is designed to discharge at predevelopment rates. **Figure 4-14** shows an example configuration of a parking stormwater chamber.

Underground chambers are used for new developments in which land cost are high and/or there is limited land available for above-ground stormwater management infrastructure. The chamber system is contained within the site and ensures no net increase in post development peak runoff. However, the chambers do not provide any stormwater treatment, so additional water quality treatment practices are required. Chamber systems typically have a service life of 50 years depending on the construction material, but they are challenging to maintain and clean.

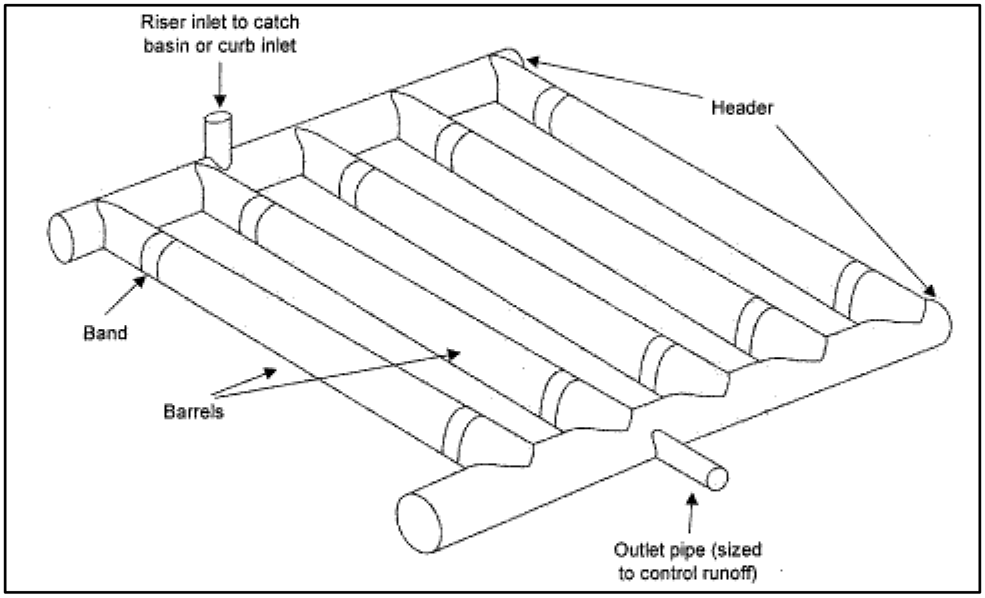

Figure 4-14- Example configuration of Parking Stormwater Chamber

A summary of design considerations for evaluating the suitability of implementing a dry retention system is summarized in **Table 4-10**. The size, shape, and characteristics of the site will determine the design of the system and if pipes or storage structures are utilized.

Table 4-11 – Parking Stormwater Chamber Design Considerations

Parameter	Consideration
Treatment Area	Urban areas with limited surface space available or high land costs.
Pretreatment Area	A separate form of pretreatment is required.
Proximity to building Foundation	Determined by material of system and access for maintenance and cleaning. Cannot be located under buildings.
Construction Material	Concrete is only used for rectangular vaults and pipes in continuous space without angles. HDPE and CMP pipes can have irregular and angled spaces, and requires minimum spacing between pipes, however they can corrode depending on soil conditions.
Soils	If system uses perforated pipes, the minimum soil hydraulic conductivity is $1x10^{-5}$ cfs/ft^2/ft. Soil condition must be tested to ensure CMP and HDPE pipes will not be corroded.
Depth and Area of Excavation	Depth of excavation must be deep enough to contain and provide stability for the system. Aluminum pipes require greater excavation depth than concrete pipes of the same diameter.
Fill Material	Concrete pipes do not require fill for stability, aluminum and HDPE pipes require more fill above for stability.
Depth of Water Table	Pipe invert should be at or above the water table whenever possible and is required if using HDPE pipes.
Inlet and outlet control	Control elevation determined by groundwater table, or lowest pipe inlet elevation. Weir or other control structure required.
Maintenance	Periodic monitoring. Accumulated trash and sediment must be cleaned out. Baffles are not required, but recommended to prevent clogging if using perforated pipe.
Hydrologic Design	Determine by State or local agency

5.0 LID HYDROLOGIC ANALYSIS

A hydrologic/hydraulic evaluation is used to determine the amount of surface water storage (retention) and/or infiltration (groundwater recharge) is needed for a particular development to control the peak runoff rate and overall volume of runoff generated during storm events. Conventional stormwater treatment require post-development peak runoff rates to be maintained at, or below, the pre-development rates for the 24- or 72-hour design storm event. This usually results in an overall larger volume of stormwater runoff being discharged for a longer duration. Consequently, a pre- versus post-development runoff volume approach, using an average annual rainfall event, is recommended for the evaluation and assessment of structural LID practices. This approach is particularly appropriate for the evaluation of structural LID BMPs because they are typically designed to control or retain smaller rainfall events, which constitute approximately 80% of the annual rainfall in South Florida.

5.1 Key Hydrologic Principles

The key hydrologic principles required for the analysis and design of low impact development sites and BMPs include:

- annual precipitation and design storm events,
- rainfall abstractions,
- surface runoff, and
- groundwater recharge.

Annual precipitation and design storm event data are used for site planning and stormwater design. The key parameters used are the total depth of rainfall, intensity of the event, and duration of the event. In Miami-Dade County, the 5-, 10-, 25- and 100-year return periods are the storm events used for development design.

Rainfall abstractions occur when rainfall is evaporated, transpired, infiltrated, or otherwise retained within a site, and does not contribute to surface runoff, or offsite discharge. Infiltration of stormwater through soil is typically the greatest source of rainfall abstraction. Most site developments create and/or increase the amount of impervious area, which decreases the amount of rainfall abstraction, and results in a more rapid accumulation of rain water on land surfaces and an increase of the offsite stormwater runoff.

Rainfall abstraction is quantified by the depth of water that does not contribute to a site's surface runoff. When natural areas are developed, the alteration of site runoff characteristics is likely to cause an increase in the volume, velocity, and frequency of runoff flows. These modified runoff flow conditions contribute to flooding, a reduction in the capacity of the City's drainage systems, accelerated erosion, and a reduction in groundwater recharge. According to the *Low-Impact Development Hydrologic Analysis* from Prince George County, MD in 1999, rainfall accounts for 10 to 30 percent of the total annual rainfall volume of a natural, undeveloped site. Depending on the level of development and the site planning methods used, development of the site can increase the surface runoff from the site to over 50 percent of the annual runoff volume. **Figure 5-1** shows the runoff variability with increased impervious surfaces.

Groundwater recharge is the percolation of surface runoff into the groundwater. A significant reduction or loss of groundwater recharge leads to the lowering of the groundwater water table and a reduction of the base flow within streams, canals, and well-fields. Lowering of the groundwater table greatly increases the likelihood of salt water intrusion and promotes the migration of contaminants.

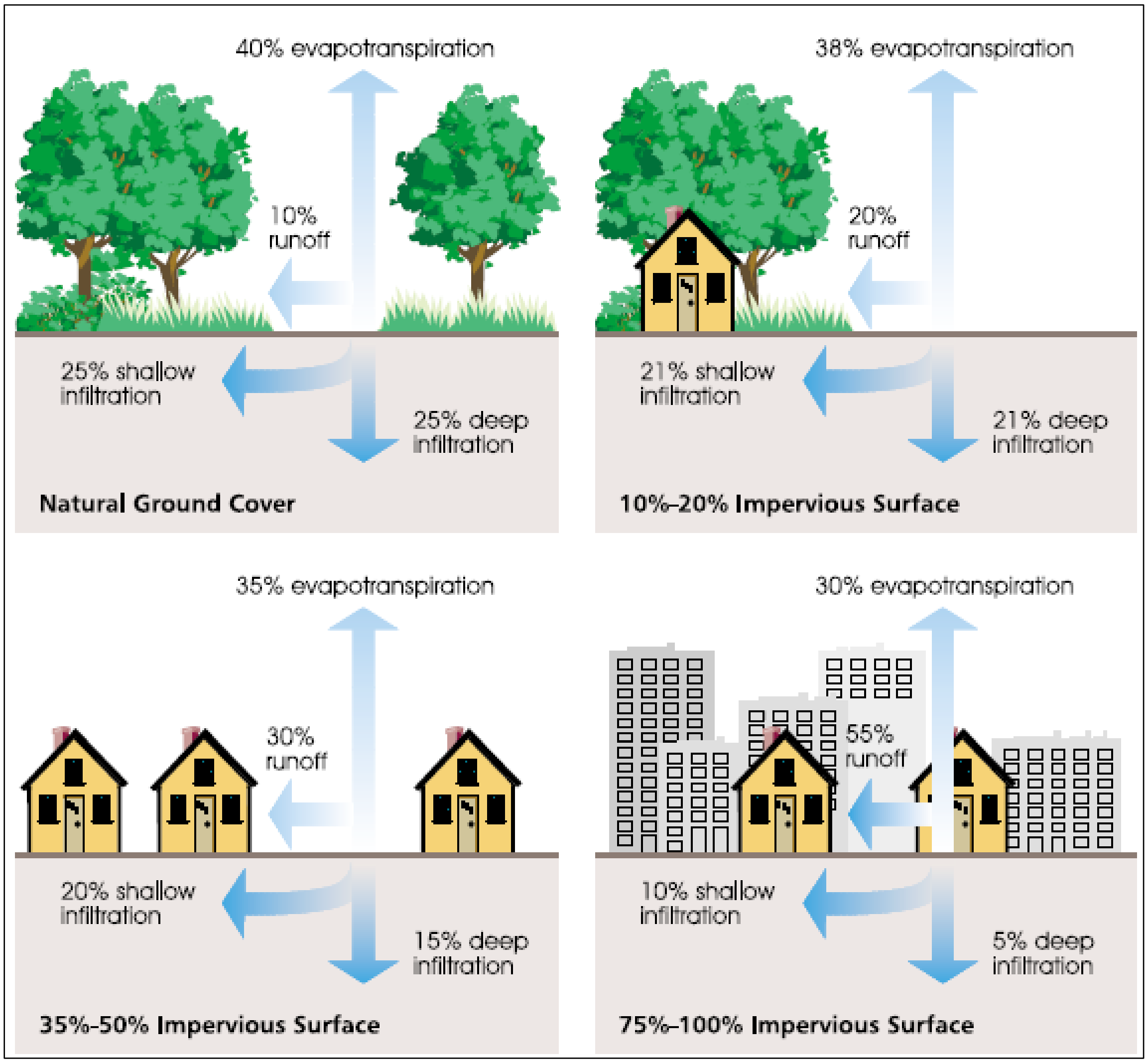

Figure 5-1 – Surface Runoff Variability with Increased Impervious Surfaces

LID techniques emulate the pre-development retention and infiltration functions of the development site through runoff volume control, peak runoff rate control, and water quality control. Implementation of LID practices preserve or increase rainfall abstraction volumes through maintenance of the site's infiltration, evaporation, transpiration, and storage potentials. In addition, LID practices aim to lengthen the travel time of surface runoff, which reduces the rapid concentration of surface runoff and lessens the load on the City's drainage system.

5.2 Hydrologic Evaluation

Hydrologic evaluation of a development site predicts the volume and flow rate of surface water generated during different storm events based on the developments topography, geology, and amount of impervious area. Appropriate LID techniques are then selected to attenuate any additional surface water generated as a result of modifying the existing site. Stormwater management systems that utilize LID technologies may have a centralized stormwater management system to assist in peak release rate control. The additional source control is provided by LID BMPs dispersed throughout the development area to control the amount of runoff volume. LID techniques aim to control the smaller and more frequent rainfall events, which are usually less than a 2-year return period, but generate most of the runoff in urban watersheds such as that found in the City of Doral.

The primary structural LID BMPs and practices that are most applicable to the City, include the following:

- Bioretention Basins or Rain Gardens
- Tree Box Filters or Infiltration Planters
- Vegetated Swales
- Filter Strips or Vegetated Buffers
- Infiltration Trench
- Exfiltration Trench or French Drains
- Green Roofs/Rain Barrels or Cisterns
- Permeable Pavement
- Detention Ponds
- Parking Chambers

When designing these LID systems, greater attention to runoff abstraction potentials has to be considered than when designing conventional systems. Abstraction potential is defined as the ability of the landscape to retain runoff with minor surface storage, such as puddles, evapotranspiration from vegetation, and groundwater recharge. Antecedent soil moisture conditions prior to a storm event also require greater attention when designing for smaller, more frequent storm events. As set forth in *The Stormwater Quality Applicant's Handbook, Section 3.1. Florida Department of Environmental Protection, March 2010 Draft,* a stormwater treatment system shall be designed to meet the minimum level of water quality treatment for nutrients and shall follow the design criteria for BMPs.

For future development and redevelopment projects within the City, it is recommended that adequate LID BMPs are also implemented to maintain the pre-development runoff volume at or below the post-development runoff. It is also recommended that the National Resources Conservation Services (NRCS) Urban Hydrology for Small Watersheds Technical Release 55 Methodologies (TR 55); SFWMD Environmental Resource Permit Applicant's Handbook Volume II (SFWMD Volume II); Standard Test Method for

Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer (ASTM D3385); Exfiltration Trench Reference Manual (ETRM) and ICPR Applications Manual (ICPR-AM) developed by the Florida Department of Transportation (FDOT) District 6; and procedures implemented by DRER are used to estimate the pre- and post-development runoff volumes. The recommended approach focuses on the following design parameters and hydrologic analysis:

- **Runoff Curve Number (CN)** is an empirical parameter established by NRCS and used in hydrology for predicting direct runoff or infiltration from excess rainfall. In Section 2-1 of TR 55, the approach to determine the CN is based on the surface-to-groundwater depth relationship. The CN is computed from sites soil storage using equation:

Equation 1 – Curve Number

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

Where, CN = Curve Number and S = Soil Storage (inches)

Soil storage in the region of the City of Doral is determined by the depth of unsaturated soil above the seasonal high groundwater elevation. The relationship between the depth to groundwater and available soil storage is provided in **Table 5-1**, from Section 5.7.4.2 of SFWMD Volume II. The table also provides soil storage values that have been adjusted to account for a 25% loss of soil storage due to the typical compaction of soils during construction.

Table 5-1 – Soil Storage (S) Relative to Depth to Groundwater (SFWMD Volume II)

Depth to Groundwater (feet)	Available Soil Storage (inches)	Available Compacted Soil Storage (inches)
1	0.6	0.45
2	2.5	1.88
3	6.6	4.95
4 or greater	10.9	8.18

- **Time of Concentration (Tc)** is the time it takes runoff to travel from the hydraulically most distant point of the site to an outlet or other point of interest within the watershed. Chapter 3 of TR 55 provides the established approach to calculate Tc.

- **Rainfall and Surface Runoff**. Rainfall is the depth of water delivered during a selected storm event. Rainfall depth is determined by measured data, an established design storm event of a given return frequency and duration, or an established average annual rainfall event. The surface runoff from a development site is the fraction of rainfall remaining after hydrologic abstractions. The approach for establishing surface runoff in the City of Doral is described in **Section 8.0.** The approach assumes the use of the average annual rainfall event established using the rain gauge data from the Miami Field Station shown in **Figure 8-1** and **Attachment F.**

- **Infiltration** is the downward, vertical percolation of rainfall into soil. The site in-situ infiltration rate in inches per hour per foot of head is determined by performing a Double-ring test in accordance with ASTM D3385.

- **Exfiltration** is the lateral or horizontal withdraw of rainfall through a French drain or gravel trench. Exfiltration rates and capacity are established by methodologies described in the ETRM and ICPR-AM.

- **Evapotranspiration** is the sum of evaporation and plant transpiration from the site to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, vegetation, and waterbodies. Transpiration accounts for the movement of water within a plant and the loss of water as vapor through stomata of the plant leaves. Use **Equation 20** from **Section 7.11** to estimate the annual evapotranspiration volume. The equation was used by the University of Florida Cooperative Extension Service Institute of Food and Agricultural Sciences,

- **Irrigation** is the artificial application of water to the land or soil. The majority of irrigation water within Doral is used for agriculture, maintenance of landscapes, and revegetation of disturbed soils. Irrigation water demand is the highest in dry areas and during periods of inadequate rainfall. An equation, used by the University of Florida Cooperative Extension Service Institute of Food and Agricultural Sciences, for estimating annual irrigation volume is provided in **Section 7.11**.

5.3 Additional BMP Analysis Methodologies

LID BMP benefits and functions are not limited to their flow volume and flow peak reduction capabilities. LID BMPs can also provide benefits of heat island reduction, vegetated shade areas, habitat for wildlife, enhanced aesthetics in the community, and reduced impact on infrastructure. LID BMPs perform functions related to volume and peak flow reduction, but also may perform functions of water treatment and groundwater recharge.

Table 5-2 describes the functions and benefits of each of the BMPs described in the previous LID BMP sections. By considering these BMP functions and benefits in the analysis of LID BMP implementation, it will encourage implementation of a greater variety of BMPs that serve a greater variety purposes than simple volume and peak flow reductions.

Table 5-2 – BMP Functions and Benefits Matrix

Best Management Practice (BMP)	Functions[18]						Benefits[18]				
	Flow Control	**Detention**	**Retention**	**Filtration**	**Infiltration**	**Treatment**	**Heat Island Mitigation**	**Shade**	**Habitat**	**Aesthetics**	**Reduced Impact on Infrastructure**
Wet Detention Pond with Aquatic Vegetation	x	x	x	x	x	x	x	x	x	x	x
Wet Retention Pond with Aquatic Vegetation	x		x	x	x	x	x	x	x	x	x
Bioretention Basin / Rain Garden	x		x	x	x	x	x	x	x	x	x
Tree Box Filters / Infiltration Planter	x		x	x	x	x	x	x	x	x	x
Vegetated Swale	x	x		x	x	x	x	x	x	x	x
Green Roof	x	x		x	x	x	x	x	x	x	x
Detention Pond	x	x		x	x		x	x	x	x	x
Retention Pond	x		x	x	x		x	x	x	x	x
Filter Strip / Vegetated Buffer	x	x		x	x		x	x	x	x	x
Infiltration Trench	x	x	x	x	x						x
Exfiltration Trench / French Drain	x	x	x	x	x						x
Permeable Pavement - Permeable Pavers				x	x		x			x	x
Permeable Pavement - Stabilized Aggregate				x	x		x				x
Permeable Pavement - Porous Asphalt				x	x		x				x
Permeable Pavement - Porous Concrete				x	x		x				x
Permeable Pavement - Structural Grids				x	x		x				x
Stormwater Chamber	x	x	x								x
Rain Barrels / Cisterns	x	x	x								x

[18]Functions and benefits of BMPs based on City of Mesa, AZ LID Toolkit

6.0 LID DESIGN CRITERIA

6.1 Bioretention Basins or Rain Gardens

Bioretention facilities should be located close to the source of runoff. Bioretention areas can be incorporated into either new or retrofit sites based on the site-grading plan. They are not recommended in areas where slopes adjacent to the facility exceeds 20% due to the risk of erosion and should not be constructed in locations where removal of native trees is required. **Figure 6-1** shows a typical cross section of a Bioretention. Typical locations are near parking lots, in traffic islands and near building roof leaders as shown in **Figure 6-2.**

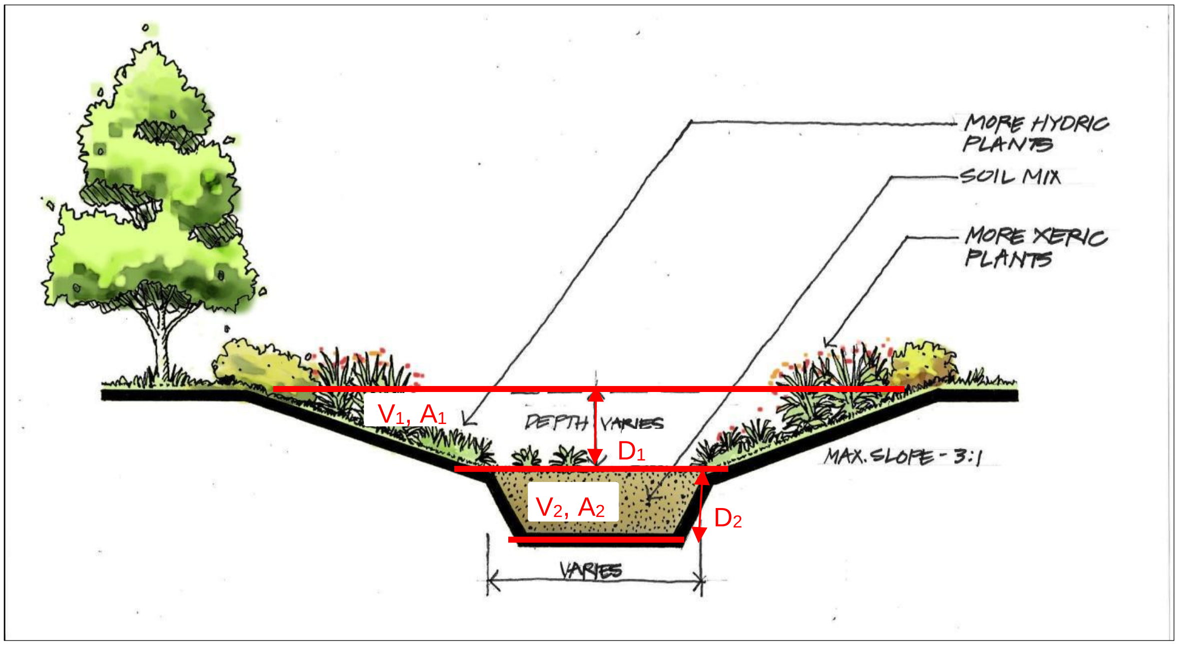

Figure 6-1 – Bioretention Basins Cross Section

Figure 6-2 – Rain Garden at Doral Starbucks

6.1.1 Design Criteria

a) Suitable for individual lots in subdivisions or common areas, other landscaped areas, and some retrofit projects.
b) Soil conditions: Where infiltration rates are below 0.1 inches per hour, bioretention must be designed with underdrains or soil augmentation to improve function.
c) Topography: Bioretention BMPs may be difficult in areas where slopes are 10% or greater. Detailed engineering and geotechnical analysis must be completed prior to site clearing and implementation.
d) Depth of Water Table: Bioretention is not suitable if there is less than one foot of separation between the seasonal high water table and the bottom of the bioretention area, unless an alternative design can be shown to be appropriate for the specific site.

6.1.2 Inspection, Operation and Maintenance Requirements

Bioretention areas must be inspected periodically to ensure they are functioning as intended and ensure that stormwater is infiltrating within 72 hours of a storm event. The inspection should include checking for any erosion and if erosion is observed, repair as necessary. Invasive plants must be removed. The health of desirable plants should be checked; and if not healthy, they must be replaced. Excess plant growth should be trimmed or thinned, and any decaying plant material removed. Mulch should be replaced annually, and accumulated trash and sediment must be cleaned out. Removing built up sediment and debris should be the priority, as neglect may impair the long term effectiveness of the bioretention area.

The soil's infiltration capacity should be inspected after a rain event to determine whether the treatment volume is being recovered as designed. Routine maintenance may seem like an unnecessary expense, but long term neglect tends to cause larger structural problems that are much more expensive to repair. The maintenance costs over the life-time of a retention pond is generally more significant than its initial construction cost; therefore, maintenance must be included in the planning. A legally binding provision to fund life-time maintenance, or adequate funds in a separate account to cover expected maintenance may be required as part of initial construction budget.

6.2 Tree Box Filters or Infiltration Planters

Tree box filters or infiltration planters are similar to bioretention systems as they use vegetation and amended soils to filter and retain stormwater. Runoff from surrounding impervious surfaces is directed into box planters to provide source control treatment, allow for a small amount of retention within the growing media, and depending on subsoil types, facilitate deep infiltration. If infiltration is not an option, a perforated under-drain placed near the bottom of the box planter will convey excess water to the storm drainage system or reservoir for reuse purposes. **Figure 6-3** shows a typical cross section of an infiltration planter. Tree box and infiltration planters are often designed for highly urbanized areas and can be retrofitted in existing developments. Examples of a typical infiltration planter and a tree box filter that were retrofitted are shown in **Figure 6-4.**

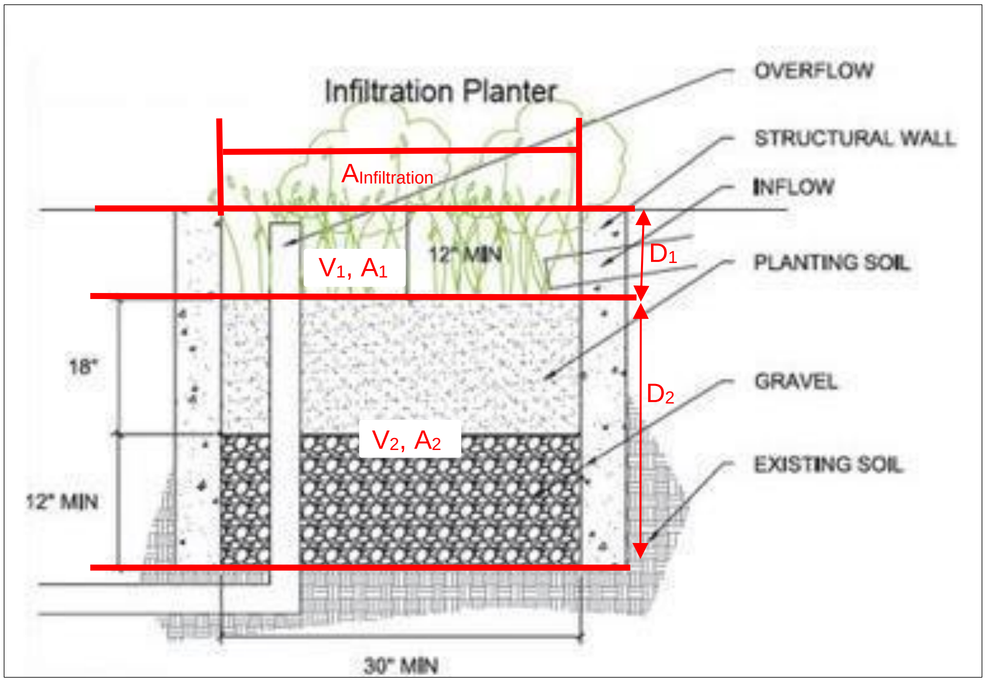

Figure 6-3 – Infiltration Planter Cross Section

Figure 6-4 – Infiltration Planter and Tree Box

6.2.1 Design Criteria

If trees are to be planted, the volume of soil provided must be considered carefully. It must be adequate for root development or the tree will not grow to a full size, and its health may be impacted. At maturity, tree roots often extend more than twice as far as the tree's canopy. In urban settings, that ideal volume is usually not available, but the reduction in volume of soil will directly impact the potential size of the tree. For example, a tree box containing 120 cubic ft of soil (typically a 4' x 10' x 3' tree box) can allow the tree canopy to spread to a 10 ft diameter before the tree growth begins to decline. The same tree planted in a box containing 500 cubic ft of soil could be expected to grow to a diameter of more than 20 ft.

Void spaces in the soil are necessary for the tree to obtain both water and air, so it is important that the surrounding soil is not compacted. A design reference for tree boxes can be found at: http://www.LID-stormwater.net/treeboxfilter_home.htm

Key design considerations include:

- Stormwater can enter tree boxes or infiltration planters through grating if the surrounding pavement is graded toward them.
- Curb cuts may be used as entry points for runoff to enter the tree box or infiltration planter.
- Infiltration beds should a minimum of 10 feet from building foundations, but each site must be considered individually. If they are located near buildings or roadways, waterproof liners may be needed to protect building foundations or street subgrade. Plastic sheeting, geo-membrane liners, or concrete walls are also possible options.
- The composition of soil both in and under the box/planter, must be evaluated, and usually amended with organic matter to improve moisture retention and microbial action. Other soil amendments may be required based on the soil type being used.
- Avoid soil compaction.
- Mulch or gravel must be placed on top of the soil, 4 inches of pine bark mulch or 2 inches of pea gravel.
- If trash, or sediment, is likely to be accumulated in the tree box or infiltration planter, a catch basin, grate, or other type of screening chamber is recommended to be installed for pretreatment before runoff enters the box.
- Provisions for overflow or diversion of high flows must be included in the design.

6.2.2 Inspection, Operation and Maintenance Requirements

If commercially manufactured boxes/planters are used, the first two years of maintenance are often included in the purchase price. After establishment, the trees or other plants should only need inspected for maintaining the health of the plants, removing any dead plant material, and pruning. The addition of mulch should be completed on a semi-annual basis. More frequent trash or debris removal may be required depending on the location.

6.3 Vegetated Swales

Swales have been used for conveyance of stormwater along roads for decades. However, swales can also be used for stormwater treatment, especially as part of a BMP treatment train, when properly designed and maintained to provide retention and infiltration of stormwater.

Swales are defined in Florida Statutes, Chapter 403.803(14) as “a manmade trench which:

1. Has a top width to depth ratio of the cross-section equal to or greater than 6:1, or side slopes equal to or flatter than 3 feet horizontal to 1 -foot vertical;

2. Contains contiguous areas of standing or flowing water only following a rainfall event;
3. Is planted with or has stabilized vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake (refer to **Attachment D** for Florida Friendly Landscapes); and
4. Is designed to take into account the soil erodibility, soil percolation, slope, slope length, and drainage area so as to prevent erosion and reduce pollutant concentration of any discharge."

Swales are inline retention systems and their treatment effectiveness is directly related to the amount of the annual stormwater volume that is infiltrated. Swales designed for stormwater treatment can be classified into two categories:

1. Swales with swale blocks or raised driveway culverts
2. Swales without swale blocks or raised driveway culverts

An example of vegetated swales in the City of Doral can be seen in **Figure 6-5**.

Figure 6-5 – Collection Suites Doral Vegetated Swale Example

6.3.1 Swales with Swale Blocks or Raised Driveway Culverts (Linear Retention Systems)

A swale with swale blocks or raised driveway culverts is essentially a linear retention system in which the treatment volume is retained and allowed to percolate. The treatment volume necessary to achieve the required treatment efficiency shall be routed to the swale and percolated into the ground before discharge. This type of swale system is recommended when multiple inflows occur to a swale.

6.3.2 Swales without Swale Blocks or Raised Driveway Culverts (Conveyance Swales)

Conveyance swales are designed and constructed to required dimensions to properly convey and infiltrate stormwater runoff as it travels through the swale. These swales are designed to infiltrate a defined quantity of runoff (the treatment volume) through the permeable soils of the swale floor and side slopes into the shallow ground water aquifer immediately following a storm event. **Figure 6-6** shows a typical cross-section of a Conveyance Swale without swale blocks.

Turf or other acceptable vegetation is established to prevent erosion, promote infiltration and stabilize the bottom and side slopes. Soil permeability and water table conditions must be such that the swale can percolate the required runoff volume. Conveyance swales may be part of a BMP treatment train providing pre-treatment of runoff before its release into another BMP depending upon the site conditions, the location of inflows, and the land use plan. **Figure 6-7** shows a typical vegetated swale that is used for a residential and parking lot area.

The swale holds water only during and immediately after a storm event, thus the system is normally "dry." These types of swales are "open" conveyance systems. This means there are no physical barriers such as swale blocks or raised driveway culverts to impound the runoff in the swale prior to discharging = to the receiving water. In these types of swales, the inflow of stormwater occurs at the "top" of the swale system and the retention volume and associated stormwater treatment credit is based on the infiltration that occurs as the stormwater moves down the swale.

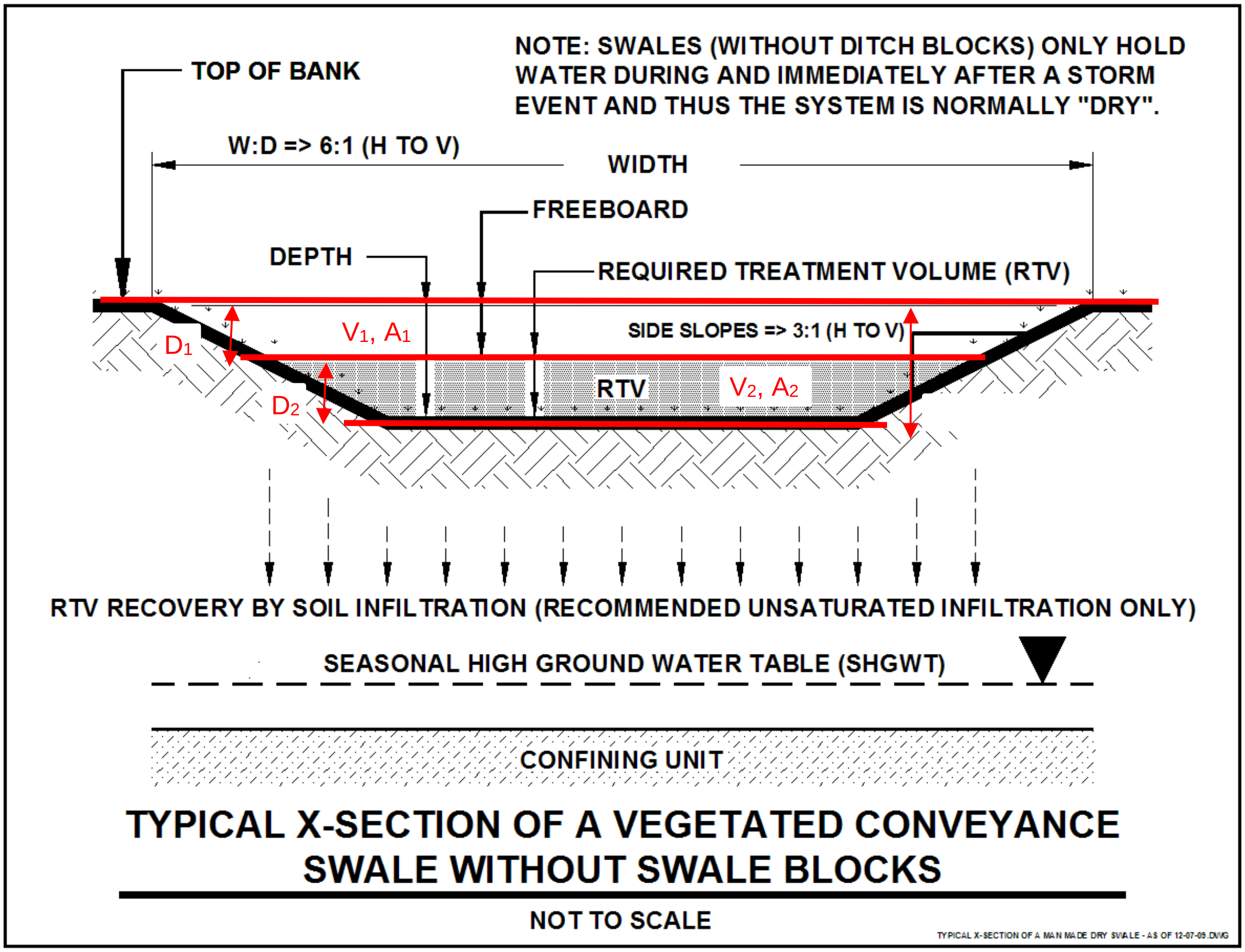

Figure 6-6 – Typical Cross-Section of a Vegetated Conveyance Swale

Figure 6-7 – Vegetated Swale in a Residential Area and a Parking Lot

6.3.3 Design Criteria

a) The seasonal high ground water table shall be at least one foot below the bottom of the swale unless the applicant demonstrates based on plans, test results, calculations or other information that an alternative design is appropriate for the specific site conditions.
b) The minimum infiltration rate through the vegetation and soil shall be at least one inch per hour.
c) The lateral slope across the bottom of the swale shall be flat to ensure even sheet flow and prevent channelized flow and erosion.
d) Longitudinal slopes shall not be so steep as to cause erosive flow velocities.
e) It is recommended that the bottom of the swale be at least two feet wide to facilitate mowing.
f) Off-street parking or other activities that can cause rutting or soil compaction is prohibited.
g) Swales shall not be constructed within 50 feet of a public or private potable water supply well.

6.3.4 Inspection, Operation and Maintenance Requirements

Typically, swales lose infiltration capacity due to clogging of the porous soils which slows recovery of the stormwater treatment volume and often results in standing water within the swale. Clogging can result from sedimentation and result in sealing of the bottom or side slope soils. It can also occur from excessive loading of oils and greases or from excessive algal or microorganism growth.

To determine if a swale is properly functioning or if maintenance is required, the swale shall be inspected shortly after a storm event. The inspection should determine if the swale is recovering its storage volume within its permitted time frames, generally 24 to 72 hours after a storm. If this is not occurring and resulting in standing water, then the cause of must be determined and appropriate actions undertaken beginning with those specified in the system's Operation and Maintenance Plan.

a) Inspection items:

    - Inspect swale for storage volume recovery within the permitted time, generally less than 72 hours. Failure to percolate the required treatment volumes indicates reduction of the infiltration rate and a need to restore system permeability
    - Inspect and monitor sediment accumulation on the bottom of the swale or at inflows to prevent clogging of the swale or the inflow pipes.
    - Inspect vegetation of bottom and side slopes to ensure 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 swale to determine if filling, excavation, construction of fences, or other objects are obstructing the surface water flow in the swales.
- Inspect the swale to determine if it has been damaged, whether by natural or human activities.

a) Maintenance activities to prolong service life:

- If needed, restore infiltration capability of the swale to ensure it meets permitted requirements.
- Remove accumulated sediment from swale and inflow or outflows and dispose of properly. Please note that stormwater sediment disposal may be regulated under Chapter 62-701, F.A.C. Sediment removal should be done when the swale is dry and when the sediments are cracking.
- Remove trash and debris, especially from inflow or outflow structures, to prevent clogging or impeding flow.
- Maintain healthy vegetative cover to prevent erosion of the swale bottom or side slopes. Mow grass as needed and remove grass clippings to reduce nutrient loadings.
- Eliminate mosquito breeding habitats.
- Remove fences or other obstructions that may have been built in the swale system.
- Repair any damages to the swale system so that it meets permitted requirements.

6.4 Filter Strips or Vegetated Buffers

Vegetated Buffer strips are sloping planted areas designed to allow stormwater to naturally infiltrate sheet flow from adjacent impervious areas. These are well-suited to addressing runoff from roads and highways, roof downspouts, and parking lots. Other advantages are they require minimal maintenance, establish habitat for birds and other pollinators, and are aesthetically pleasing. A schematic of a typical Vegetated Buffer and its contributing area is presented in **Figure 6-8.** Shown in **Figure 6-9** are typical vegetated buffers for a residential and roadside area.

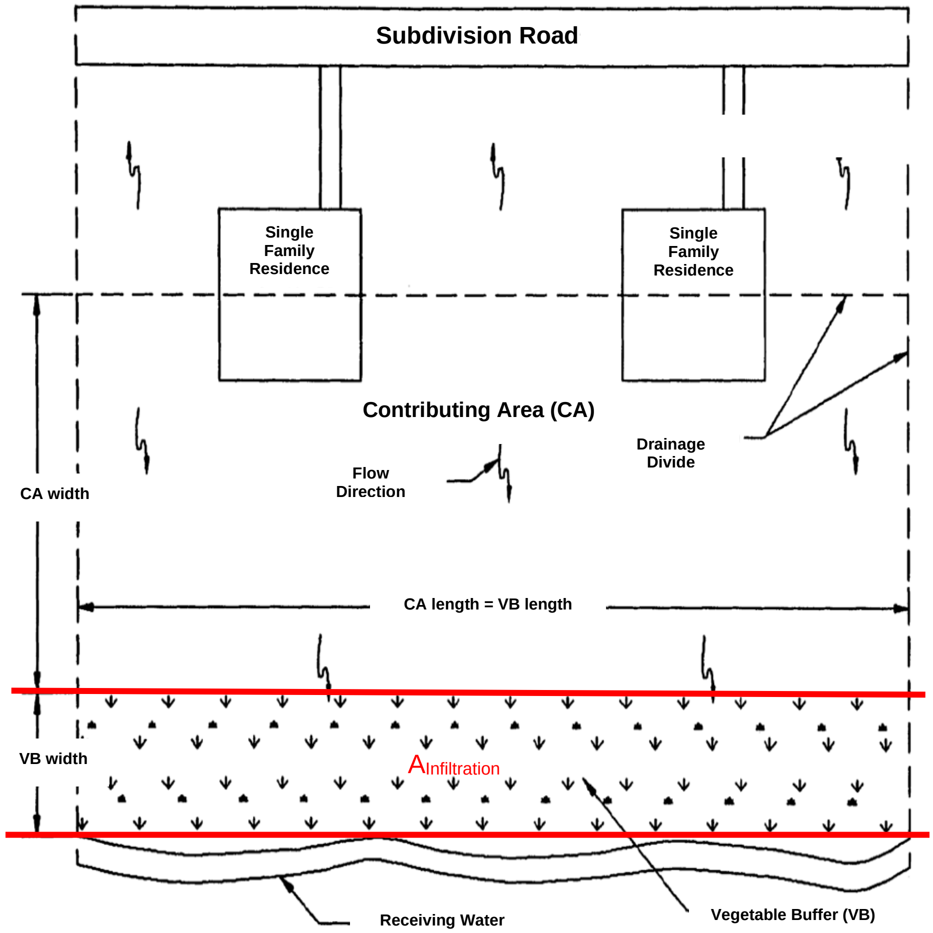

Figure 6-8 – Plan View Schematic of a Typical Vegetated Buffers

Figure 6-9 – Vegetated Buffer Strip

6.4.1 Design Criteria

a) The contributing area is defined as the area that drains to the vegetated buffer, such as roads and highways, roof downspouts, and parking lots
b) The seasonal high ground water table shall be at least one foot below the bottom of the vegetated buffer unless the applicant demonstrates based on plans, test results, calculations or other information that an alternative design is appropriate for the specific site conditions.
c) The minimum infiltration rate through the vegetation and soil shall be at least one inch per hour.
d) The minimum buffer width (dimension parallel to flow direction) shall be 25 feet to provide adequate area for infiltration and the maximum vegetated buffer width shall be 100 feet to ensure sheet flow conditions and the integrity of the treatment system. Factors affecting the minimum width (measured parallel to the direction of runoff flow) of vegetated buffer include infiltration rate, ground slope, rainfall, cover and soil characteristics, depth to water table and overland flow length. Infiltration is the primary means of treatment in vegetated buffers.
e) The maximum slope of vegetated buffer shall not be greater than 6:1.
f) The length of the buffer (measured perpendicular to the runoff flow direction) must be at least as long as the length of the contributing runoff area (see **Figure 6-8**).
g) Runoff from the adjacent contributing area must be evenly distributed across the buffer strip to promote overland sheet flow. If the flow regime changes from overland to shallow concentrated flow, the buffer is effectively “short-circuited” and will not perform as designed.
h) The Property Association Documents and Conditions Covenants and Restrictions (CC&R’s) will require that the contributing area must be stabilized with permanent vegetative cover that is consistent with the Florida Friendly Landscaping program (see Attachment B) and which is fertilized only with Florida-friendly fertilizers.
i) A legal reservation, in the form of an easement or other limitation of use, must be recorded which provides preservation of entire area of the vegetated buffer. The reservation must also include access for maintenance of the vegetated buffer unless the operation and maintenance entity wholly owns or retains ownership of the property.
j) The vegetated buffer area will be an existing undeveloped area which contains existing or planted vegetation suitable for infiltrating stormwater and soil stabilization. The existing vegetation must not be disturbed during or after the construction of the project. If the vegetated buffer will be planted, the proposed list of Florida-friendly plants must be submitted to the City for review. Maintenance shall ensure that the vegetated buffer contains less than 10 percent coverage by exotic or nuisance plant species.
k) Erosion control measures must be used during development of the contributing area so as to prevent erosion or sedimentation of the vegetated buffer.
l) Vegetated buffers shall not be constructed within 50 feet of a public or private potable water supply well.
m) The vegetated buffer and any required wetland buffer can be the same area provided that the functions and regulatory requirements for each are met.

6.4.2 Inspection, Operation and Maintenance

Maintenance of vegetated buffers are related to integrity of the vegetated buffer and damage to the natural or planted vegetation or the infiltration capabilities within the vegetated buffer. To determine if the vegetated buffer is properly functioning or whether it needs maintenance requires that an inspection be done during and soon after a storm. The inspection should determine if the vegetated buffer is providing sheet flow and infiltration of the required treatment volume within its permitted time frames, generally 24 to 72 hours after a storm. If this is not occurring, then the cause of must be determined and appropriate actions undertaken beginning with those specified in the system's Operation and Maintenance Plan.

Vegetated buffers must be inspected annually by the operation and maintenance entity to determine if there has been any encroachment or violation of the terms and condition of the vegetated buffer as described below. Reports documenting the results of annual inspections shall be filed with the City every year, or upon discovery of any encroachment or violation of design parameters, whichever occurs first.

a) Inspection items include:

- Inspect vegetated buffer for storage volume recovery within the permitted time, generally less than 72 hours. Failure to percolate the required treatment volumes indicates reduction of the infiltration rate and a need to restore system permeability.
- Inspect vegetated buffer to ensure that inflow is via sheet flow, for areas of channelized flow through or around the buffer, and for areas with erosion or sediment accumulation indicating channelized flow or that stabilization of the adjacent contributing area is needed.
- Inspect vegetated buffer for damage by foot or vehicular traffic or encroachment by adjacent property owners.
- Inspect vegetated buffer for the health and density of vegetation, and for the occurrence of exotic or nuisance plant species.

b) Maintenance activities to prolong service life:

- If needed, restore infiltration capability of the vegetated buffer to ensure it meets permitted requirements.
- Repair any areas where channelized flow is occurring and restore sheet flow.
- Repair any areas with erosion and carefully remove accumulated sediments if needed to ensure the health and functioning of the vegetated buffer
- Stabilize eroding parts of the adjacent contributing area as needed to prevent erosion and sedimentation.

- Repair any damage to the vegetated buffer by foot or vehicular traffic and remove any fences or other materials that have been placed in the vegetated buffer by adjacent property owners.
- Maintain the vegetated buffer vegetation and, if necessary, replant the vegetated buffer with approved Florida-friendly vegetation as needed to ensure sheet flow and prevent erosion and sedimentation. Maintenance of exotic or nuisance species within the vegetated buffer is not required but their removal is recommended.
- All repairs to the vegetated buffer must be made as soon as practical in order to prevent additional damage to the buffer. Repaired areas must be re-established with approved Florida-friendly or native vegetation.

6.5 Infiltration Trench

An infiltration trench is a rectangular excavation lined with a geotextile filter fabric and filled with coarse stone aggregate. These trenches serve as underground infiltration reservoirs. Storm water runoff directed to these trenches infiltrates into the surrounding soils from the bottom and sides of the trench.

Infiltration trenches can be used to intercept stormwater from landscape or open space before it crosses onto paved areas or can be used as part of a treatment train with other BMPs (such as Vegetated Buffer Strips or Vegetated Swales). **Figure 6-10** shows a typical cross-section of an Infiltration Trench. In order for infiltration trenches to be effective, they must be located in areas where the local soil is appropriate for infiltration and they must be designed accordingly. **Figure 6-11** shows a typical example of infiltration trench applications.

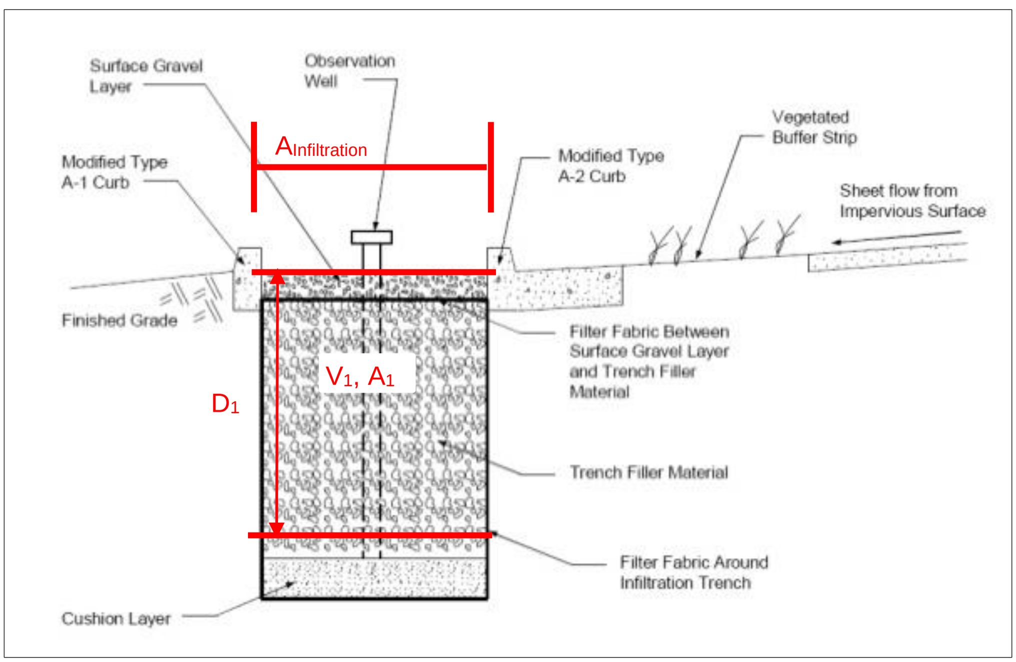

Figure 6-10 – Infiltration Trench Conceptual Drawing

Figure 6-11 – Infiltration Trench

6.5.1 Design Criteria

a) Soil must have sufficient permeability to accept water from exfiltration tanks.
b) The depth to the seasonal high ground water table must be at least one foot.
c) Modular systems wrapped in a geo-textile fabric are available, and adapt to a range of dimensions.
d) The cost of materials is greater than an equivalent surface infiltration BMP, but can be cost effective in areas with high costs for land. The cost of an equivalent reduction in size for other stormwater management facilities should be included in a comparison.
e) An underdrain (infiltration pipe) can be used as a back-up to withdraw water if the system becomes clogged.

6.5.2 Inspection, Operation and Maintenance

The most important maintenance requirement is to prevent sediment from washing onto and clogging the media and surrounding gravel or sand. The design should include some type of observation well to monitor the rate of exfiltration from the tank.

6.6 Exfiltration Trenches or French Drains

An exfiltration trench is a subsurface retention system consisting of a conduit such as perforated pipe surrounded by natural or artificial aggregate which temporarily stores and infiltrates stormwater runoff. Like other types of retention systems, exfiltration trenches provide reduction of stormwater volume which reduces pollutant loads. Additionally, substantial amounts of suspended solids, oxygen demanding materials, heavy metals, bacteria, some varieties of pesticides and nutrients such as phosphorus may be removed as runoff percolates through the soil profile. **Figure 6-12** shows a generic "wet" exfiltration trench. **Figure 6-13** shows an exfiltration trench system being installed on the roadway for a residential neighborhood.

Soil permeability and water table conditions must be such that the trench system can percolate the required stormwater runoff treatment volume within a specified time following a storm event. The trench system is returned to a normally "dry" condition when drawdown of the treatment volume is completed. Similar to retention basins, the treatment volume in exfiltration trench systems is not discharged to surface waters.

Because of the unique hydrogeological conditions found in Miami-Dade County, exfiltration trenches are not typically designed to be completely above the SHGWT as is the case in the rest of the state. These systems are termed "wet" exfiltration trenches as shown in **Figure 6-12.**

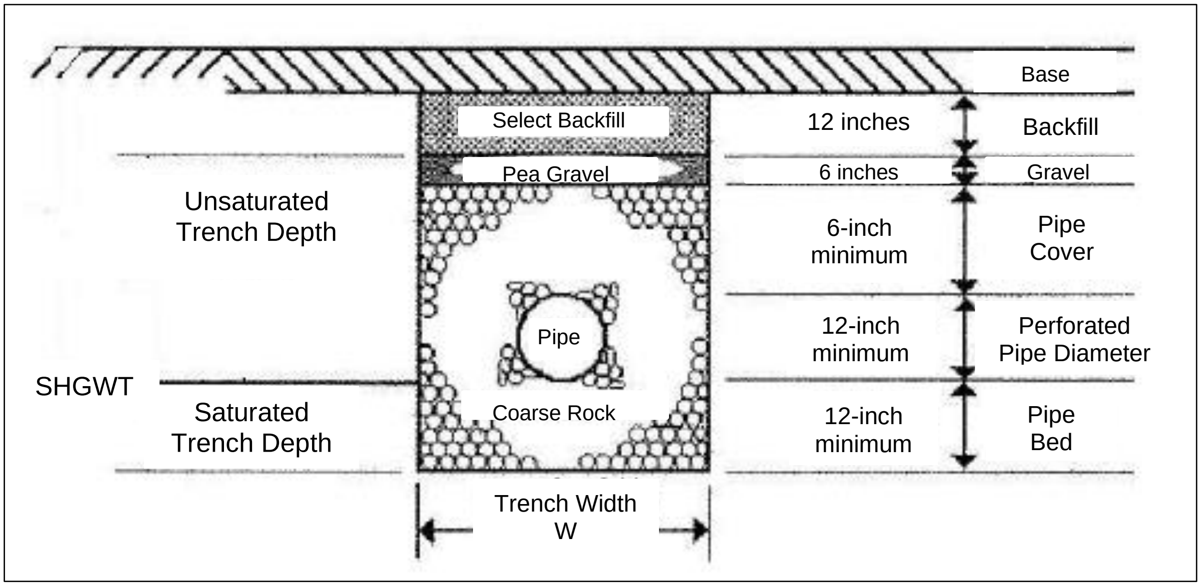

Figure 6-12 – Generic "WET" Exfiltration Trench

Figure 6-13 – Exfiltration Trench

6.6.1 Design and Performance Criteria

a) Exfiltration trenches must have the capacity to retain the required treatment volume without a discharge and without considering soil storage.
b) The required treatment volume initially shall be retained in the perforated/slotted pipe and the surrounding aggregate reservoir.
c) Exfiltration trenches shall only be permitted for projects to be operated by entities with single owners or entities with full-time maintenance staffs.
d) The exfiltration trench must provide the capacity for the required treatment volume of stormwater within 72 hours, with a safety factor of two, following a storm event assuming average antecedent runoff condition (ARC 2). In exfiltration systems, the stormwater is drawn down by natural soil infiltration and dissipation into the ground water table as opposed to underdrain systems which rely on artificial methods such as drainage pipes.
e) Minimum perforated or slotted pipe diameter shall be twelve (12) inches.
f) Minimum aggregate reservoir trench width shall be three (3) feet.
g) To ensure recovery of the Required Treatment Volume (RTV), a dry exfiltration trench must be designed so that the invert elevation of the trench must be at least one foot above the seasonal high ground water table elevation unless the applicant demonstrates, based on plans, test results, calculations or other information, that an alternative design is appropriate for the specific site conditions.
h) Because of the unique aquifer characteristics, wet exfiltration trenches will only be allowed within Miami-Dade County.
i) To prevent surrounding soil migration into the aggregate reservoir, the reservoir must be enclosed on all sides by a permeable woven or non-woven filter fabric. The permeability of the filter fabric must be greater than the permeability of the surrounding soil.
j) To facilitate inspection of proper operation and maintenance of the exfiltration system, the system must be designed with sufficient access for inspection. Appropriate inspection access is dependent on the design of the specific system, but all must provide the ability to determine whether the system is maintaining the design infiltration rate and storage volume. Examples of acceptable inspection methods include designing the system so the terminal ends of any perforated/slotted pipe or storage areas meets one of the following criteria:
    - Terminates in an accessible drainage inlet or manhole; or
    - Has an inspection port installed with a minimum diameter of eight (8) inches
    - Has an observation well that allows checking of the recovery of the RTV
k) To provide a collection space for trash and other inflow debris, a minimum 24-inch deep maintenance sump will be required for all system inlets and manholes. A minimum twelve-inch (12”) diameter weep hole shall be placed in the bottom of the maintenance sump to facilitate the infiltration of stormwater into the underlying soils after a rainfall event.
l) To reduce the potential for trash, debris and oil/grease inflow into the exfiltration trench system; a baffle, trash tee or other equivalent device must be installed at the end of the perforated/slotted pipe(s) in all access inlets and manholes. **Figure 6-14** shows an example drawing of exfiltration trench sumps and dead-end details.

m) Sustainable void spaces must be used in computing the storage volume in the aggregate reservoir. These aggregate void space values shall be the greater of the following:
  - 35% of aggregate volume; or
  - 80% of the measured testing lab values for the selected aggregate(s), if obtained and certified by a Florida licensed geotechnical professional.

n) The material used in the aggregate reservoir shall be washed to ensure that no more than five percent (5%) of the materials passing a #200 sieve.

o) Exfiltration trenches shall not be constructed within 50 feet of a public or private potable water supply well.

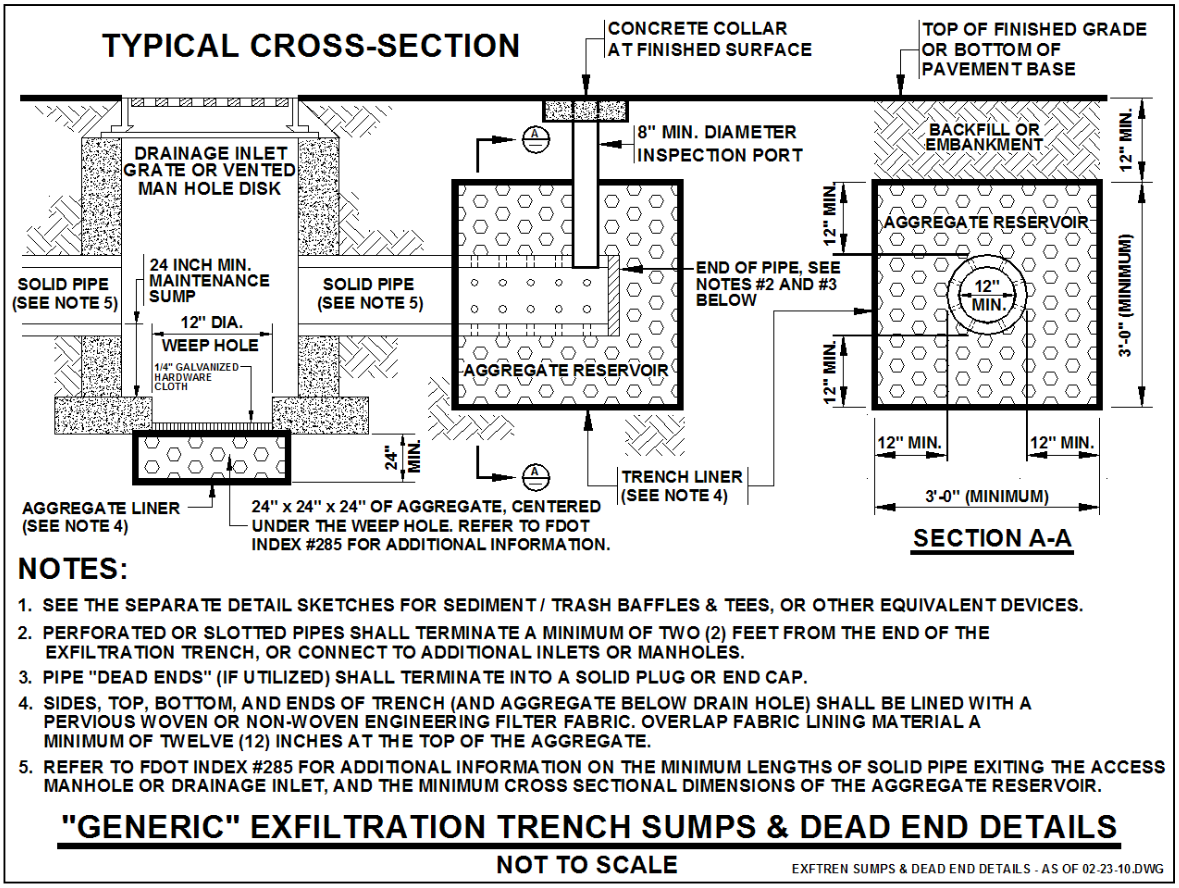

Figure 6-14 – Typical Exfiltration Trench Sumps and Dead End Details

6.6.2 Inspection, Operation and Maintenance

a) Inspection items:

  - Monitor facility for sediment accumulation in the pipe (when used) and storage volume recovery (i.e. drawdown capacity). 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. Reductions in storage volume due to sediment in the distribution pipe, also reduces efficiency. Minor maintenance measures can restore infiltration rates to acceptable levels short term. 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.

- 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.

a) Maintenance activities to prolong service life:
   - Remove sediment from sediment or oil/grease traps, catch basin inlets, manholes, and other appurtenant structures and dispose of properly.
   - Remove debris from the outfall or “Smart Box” (diversion device in the case of off-line facilities).
   - Removal of sediment and cleaning of trench system. This process normally involves facilities with large pipes. Cleanout may be performed by suction hose and tank truck and/or by high-pressure jet washing.

b) To maintain a 72-hour exfiltration rate:

   - Periodic clean-out or rehabilitation of the system to remove any accumulated trash, sediment and other inflow debris and remediate any clogging of perforated pipes.
   - Total replacement of the system. In some cases, the system may not be able to be rehabilitated sufficiently to restore the design storage and infiltration rate. In these cases, complete replacement of the system may be necessary. The applicant shall provide an estimate of the expected life expectancy of the exfiltration trench and an estimate of the cost to replace the trench.

6.7 Green Roof or Rain Barrels/Cisterns

Rainwater harvesting collects and conveys rainwater from a building roof to storage in a Rain Barrel or a Cistern for reuse in irrigation or approved non-potable uses. Components include the roof surface, gutters and downspouts, roof washer to remove contaminants, cisterns, and pumping and piping systems. A green roof/cistern system is a retention BMP and its effectiveness is directly related to the annual volume of roof runoff that is captured, retained, and reused.

Green roofs are suitable for a wide range of buildings, including industrial, educational and governmental facilities, offices, commercial properties, and residences. In general, buildings with large roof areas are targeted for stormwater management. They can be designed as part of a new construction or retrofit following a structural assessment. They also provide shade to underlying surfaces thus reducing heat transmission to the building and effectively lowering cooling costs by 25%.

There are two types of green roofs described in this report. An *Extensive Green Roof* is one where the root zone (pollution control layer and growth media layer) is less than 6 inches in depth. Whereas *Intensive Green Roofs* have root zones greater than or equal to 6 inches and are typically intended for public or private access. There are two distinct functions for green roofs, one is passive and the other is active. Passive green roofs are intended only for maintenance access and typically require less maintenance, while an active roof is used for public and private access. Green roofs can be built on any type of roof deck with a minimum slope of one inch per foot. **Figure 6-15** and **Figure 6-16** provide typical green roof details for the different types of roofs and various component details.

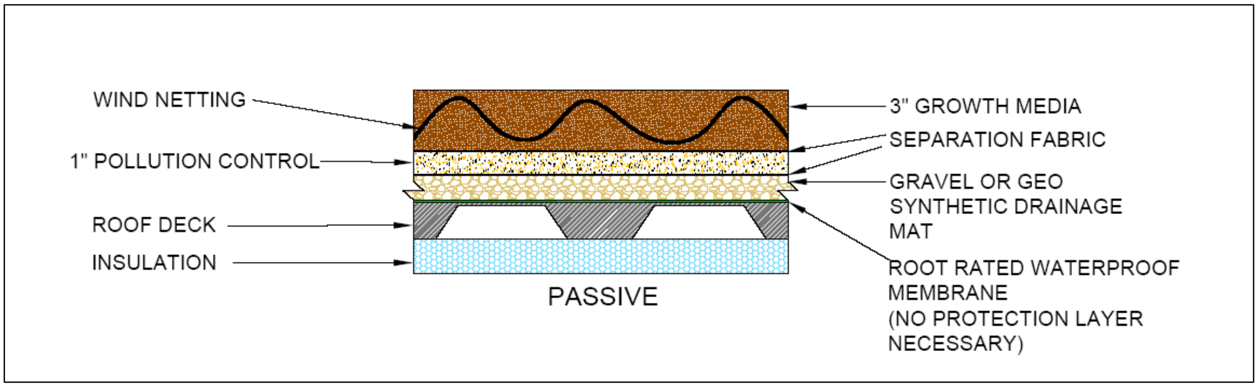

Figure 6-15 – Extensive Green Roof Section (Usually Passive Function)

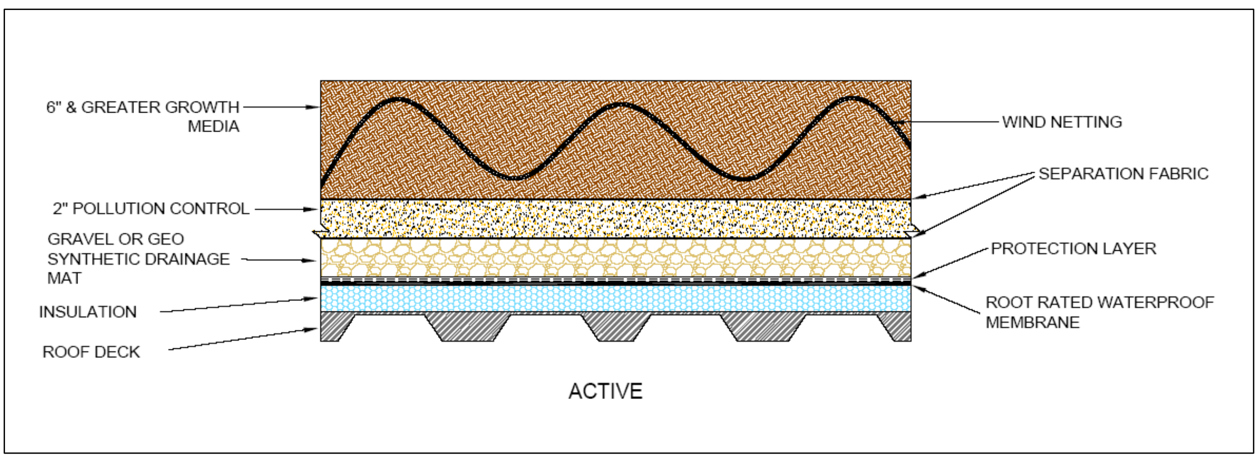

Figure 6-16 – Intensive Green Roof Section (Usually Active Function)

An example of a green roof and residential barrels/cisterns systems are provided in **Figure 6-17**.

Figure 6-17 – Green Roof and Rain Barrels/Cisterns System for Residential

6.7.1 Design Criteria

a) Waterproof Membrane - A waterproof membrane layer must be incorporated into the roof system to protect the structure from moisture damage. There are several options for this layer such as, polypropylene or polyethylene membrane, polyvinyl chloride, or spray applied elastomeric waterproofing membrane as well as others. The applicant must check with the membrane manufacturer to ensure that the membrane is rated as a root protection material. All permitted design specifications and manufacturer's installation directions shall be followed to ensure that the proposed product will function as intended with green roof overburden.

b) Drainage Layer - The major function of the drainage layer is to facilitate lateral movement of the filtrate to the point of drainage to ensure no standing water is present. The drainage layer can consist of several different materials such as gravel, recycled products, or geo-synthetic drainage mats. It is important to note that whatever material used shall not depress or elevate the pH of the filtrate more than 1.5 pH units from neutral. When using aggregate as drainage layer materials, it must contain no more than 7% "fines" (particles passing sieve number 200) by mass. The drainage material must be able to structurally support the intended green roof overburden, as well as maintenance activities, without deflection such that drainage is blocked or restricted. A non-woven geotextile separation fabric must be installed on top of the drainage layer to prevent clogging of the drainage layer. This fabric shall have a thickness to pass the drainage water and void spaces such that the pollution control media does not fill the surface void area of the drainage layer and cause clogging. The hydraulic conductivity of the fabric must exceed 1.5 inches per hour.

c) Growth Media - The growth media is intended to be the main support coarse for the vegetation. The growth media is installed on top of the separation fabric. Growth media shall meet all of the following specifications.

- Unit Weight is no more than 45 pounds per cubic foot when dry.
- No more than 10% of the particles passing the #200 sieve.
- Contains no shale.
- At least 3 inches in thickness.
- Water holding capacity is at least 30%, and as measured by porosity.
- Permeability is at least 1.5 inches per hour. Permeability is vertical hydraulic conductivity at the specified unit weight noted above.
- Organic content is no more than 10% by volume.
- pH is between 6.5 and 8.0.
- Soluble salts are less than 3.5 g (KCL)/L.

d) Preventing wind uplift – To assure that a green roof built in Florida remains operable, the green roof must be designed to prevent wind uplift. A three-dimensional netting made of polyamide (nylon) filaments connected together woven into the growth media layer or other equivalent method is acceptable. As an alternative, a parapet of sufficient height can be used. For buildings less than 100 feet tall, a parapet height of 36 inches can be used in place of wind netting.

e) Vegetation – Florida native vegetation is recommended on green roofs used for stormwater treatment. Low maintenance plants and drought tolerant plants are recommended but not mandatory because of the use of stored stormwater for irrigation. However, plants tolerant to high levels of direct sunlight and high temperatures are necessary for the success of a healthy green roof plants. Care should be made to ensure that the available root zone of the green roof is sufficient for the intended plants. When designing an intensive green roof, larger plants with more rigorous maintenance schedules are acceptable. Plants must achieve at least 80% cover of the green roof area within one year of planting. When the vegetation density is less than 80%, new plants shall be added. **Table 6-1** includes plants that have been successfully used on green roofs in the different parts of Florida. Other plants are acceptable and applicants are encouraged to consult landscape architects and native nursery personnel for appropriate plants.

Table 6-1 – Plants That Have Been Successfully Used on Green Roofs in Florida

Plant	North FL	Central FL	South FL
Muhly Grass	YES	YES	YES
Butterfly Weed		YES	YES
Blanket Flower	YES	YES	YES
Sunshine Mimosa		YES	YES
Perennial Peanut	YES	YES	YES
Snake Weed		YES	YES
Asiatic Jasmine	YES	YES	YES
Simpson Stopper		YES	
Black Eyed Susan	YES	YES	
Beach Sunflower	YES	YES	YES

For plants used on green roofs in coastal areas, salt tolerance is an important consideration. Some examples of plants used along the coast are Simpson stopper, Snake plant, Muhly grass, Inkberry, and Beach sunflower.

f) Irrigation - Irrigation is required on all green roofs in Florida to ensure plant survival. Drip irrigation applied at the growth media surface is required, usually with one foot on-center spacing. Irrigation pumps must be installed with an alarm system to signal any mechanical problems. Irrigation will vary by season and a rain shut-off sensor is required. Flow meters shall be installed as a means of documenting when irrigation occurs and the volume of water used for irrigation. The addition of make-up water will be required during parts of the year depending on local rainfall patterns and records must be kept to document how much make-up water is added. The recommended source of make-up water is stormwater or gray water, whenever available. An in-line filter is recommended to reduce the maintenance problems and cost of irrigation line replacement. Depending upon the green roof retention volume and design, irrigation shall occur three to four times per week with a maximum total application of one (1.0) inch per week if filtrate or stormwater are available.

g) Roof Drain - The green roof must drain into a storage device, typically a barrel/ cistern. The slope of the roof must be at least ¼ inch per foot. The primary drain can be an interior drain or gutter drain. A one-foot barrier must be maintained around the drain to prevent vegetation and debris from clogging drain as well as providing easy inspection. This barrier can be an aluminum break or a washed river stone section. An overflow shall also be provided to ensure drainage in the event that a clog occurs in the primary drain.

h) Barrel/Cistern or Other Water Storage Area - The barrel/cistern or other water storage area serves to store filtrate for use as irrigation. Filtrate volumes in excess of those required for irrigating the green roof can be used to either irrigate ground level landscaping or can be directed to other retention BMPs that allow for infiltration. Barrel/Cistern or other storage placement can be below ground or above ground. If an above ground barrel/cistern is used it must be UV stable, dark in color, and must be placed in areas of low to no direct sunlight. Direct sunlight may cause irrigation water temperature to get too hot for plants.

6.7.2 Inspection, Operation and Maintenance

Maintenance issues associated with green roof/cistern systems are related to the health of the plants, the drainage capabilities of the system, and proper functioning of the irrigation system. Green roof/cistern systems must be inspected annually by the operation and maintenance entity to determine if it is operating as designed and permitted. Reports documenting the results of annual inspections shall be filed with the City every year.

a) Inspection items:

- Inspect operation of the green roof/cistern system to ensure that rainfall is flowing properly through the green roof and into the cistern.
- Inspect the plants on the green roof to ensure they are healthy and growing. Ensure plants are covering at least 80% of the surface area of the green roof and that plant species not on the approved plant list are not becoming established.
- If an intensive green roof, inspect it for damage by foot traffic or other human uses of the green roof.
- Inspect the operation of the pumping system and the irrigation system to ensure they are working properly.

c) Maintenance activities to prolong service life:

- Repair any components of the green roof drainage system which are not functioning properly and restore proper flow of stormwater or filtrate.
- Maintain the plants on the green roof on an as needed basis to ensure healthy growth and meet the required 80% coverage of the green roof. Weeding to remove plants not on the approve design plant list will be needed on a regular basis. Whenever plant coverage is less than 80%, new plants shall be established as soon as possible.
- Repair any damage to the green roof by foot traffic or other human uses.
- Repair or replace any damaged components of the pumping and irrigation system as needed for proper operation.

b) Record keeping:

The owner/operator of a green roof/cistern system must keep a maintenance log of activities that is available at any time for inspection or recertification purposes. The log will include records related to the use of the filtrate water for irrigation. A flow meter to measure the quantity and day/time of irrigation is required. Visual observations of the success of plant growth and cover, including photo documentation is also required. The maintenance log shall include the following:

- Irrigation volume measured using a flow meter specifying the day and amount;
- Cistern overflow volumes and makeup water volumes;
- Observations of the irrigation system operation, maintenance, and a list of parts that were replaced;
- Pruning and weeding times and dates to maintain plant health and 80% coverage;
- A list of dead, dying, or damaged plants that are removed and replaced;
- Maintenance of roof mechanical equipment;

- Dates on which the green roof was inspected and maintenance activities conducted; and
- Dates on which fertilizer, pesticide, or compost was added and the amounts used.

6.8 Permeable Pavement

Pervious pavement systems include the subsoil, the sub-base, and the pervious pavement as shown in **Figure 6-18.** They can include several types of materials or designed systems such as pervious concrete, pervious aggregate/binder products, pervious paver systems, and modular paver systems. Pervious asphalt and pervious pavements using crushed and recycled glass will not be allowed until future improvements are made and verified with testing to address their structural capability, hydraulic performance and manufacturing process. Recent studies on the design, longevity, and infiltration characteristics of pervious pavement systems are available on the University of Central Florida's website http://stormwater.ucf.edu/.

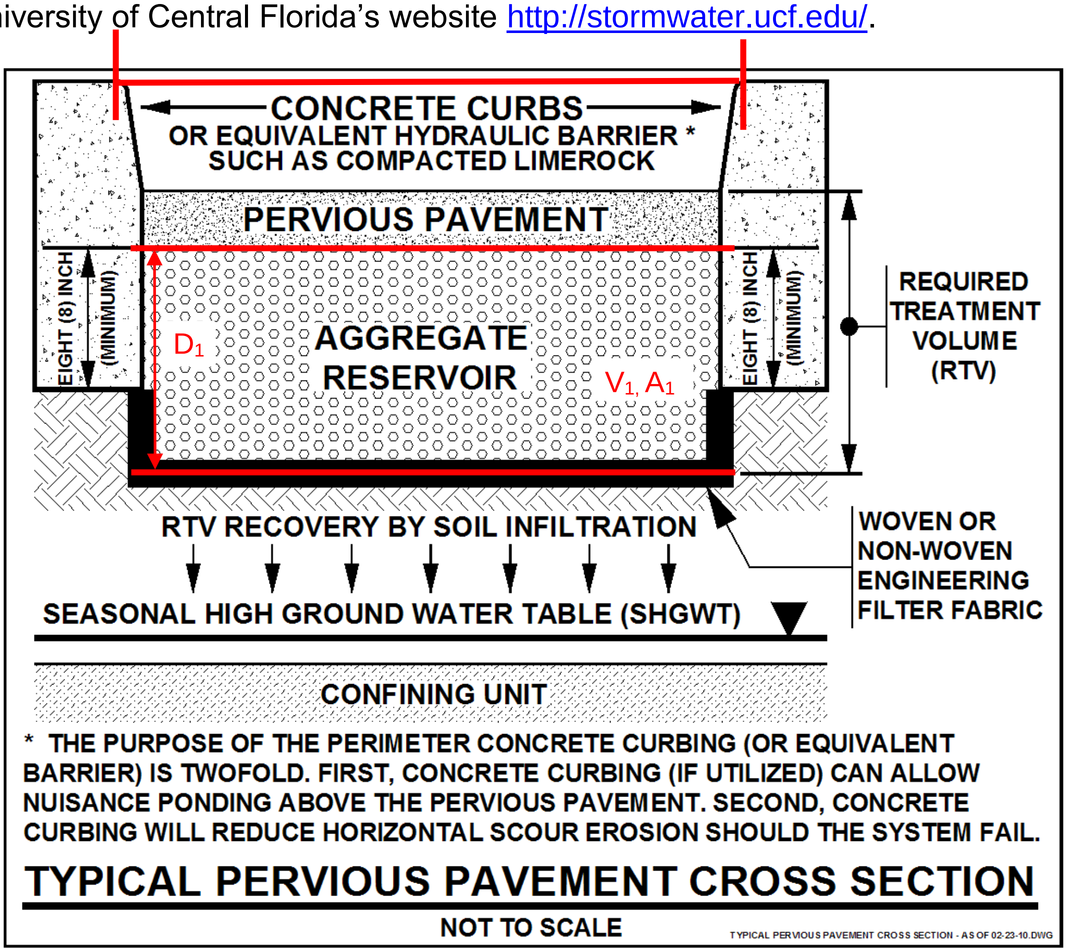

Figure 6-18 – Typical Pervious Pavement Cross-Section

Permeable pavements can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkaways as shown in **Figure 6-19**. They are ideal for sites with limited space for other stormwater LID BMPs.

Figure 6-19 – Permeable Pavement in Parking Lot and Park/Walkaway Area

6.8.1 Design Criteria

Pervious pavement system design has two major components: structural and hydraulic. The pervious pavement system must be able to support the traffic loading while also (and equally important) functioning properly hydraulically. This section does NOT discuss structural designs of pervious pavement systems. Engineering consultants should consult the product manufacture's pavement design standards to ensure that pervious pavements will be structurally stable, and not be subject to premature deterioration failure.

Below are the types of practices, specifications, recommendations, tools and potential conditions for applicants to consider for the approval of pervious pavement systems. This is not intended to cover all potential designs. Professional judgment must be used in the design and review of proposed pervious pavement systems.

a) The applicant must provide reasonable assurances that the pervious pavement construction will be performed by a contractor trained and certified by the product manufacturer to install the proposed pervious pavement system.
b) The seasonal high ground water table shall be at least one foot beneath the bottom of the pervious pavement system unless the applicant demonstrates, based on plans, test results, calculations or other information, that an alternative design is appropriate for the specific site conditions. The "system" is defined as the pervious pavement itself, the underlying storage reservoir, if used (i.e., pea rock, #57 stone, etc.), and the geo-fabric that wraps the underlying storage reservoir.
c) The pervious pavement system must provide the capacity for the recovery of the required treatment volume of stormwater within 72 hours, with a safety factor of two, assuming average Antecedent Runoff Condition (ARC 2). In a pervious pavement system, the stormwater is drawn down by natural soil infiltration and

dissipation into the ground water table, as opposed to underdrain systems which rely on artificial methods like perforated or slotted drainage pipes.

d) The minimum vertical hydraulic conductivity of the pervious pavement system shall not be less than 2.0 inches per hour.
e) Pervious pavement systems shall not be constructed within 50 feet of a public or private potable water supply well.
f) The in-situ (or imported) subgrade soil (below the pervious pavement system) shall be compacted to a maximum of 92% - 95% Modified Proctor density (ASTM D-1557) to a minimum depth of 24 inches. For proposed pervious pavements within redevelopment projects, the existing pavement section and its compacted base shall be removed. The underlying soils are to be scarified to a minimum 16-inch depth, re-graded, filled with hydraulically clean soils (if applicable) and proof rolled to a maximum compaction of 92% - 95% Modified Proctor density (ASTM D-1557).
g) Other than pedestrian walks, bicycle paths and driveway ingress or egress areas, the maximum slope for pervious pavements is 1/8 inch per foot (1.04%) although zero percent slope is preferred.
h) Except for pervious walks and bike paths, curbing, edge constraint or other equivalent hydraulic barrier will be required around the pervious pavement to a minimum depth of eight (8) inches beneath the bottom of the pavement and to the depth necessary to prevent scouring from the horizontal movement of water below the pavement surface depending on the adjacent slopes. The horizontal movement of water can cause scour failure at the edge of the pervious pavement system, or mask the hydraulic failure of the system due to plugging of the deeper voids in the pervious pavement or aggregate reservoir. The cross sectional construction drawings of the pervious pavement system and its relationship to the slopes of adjacent areas must include a demonstration that the depth of the curbing, edge constraint or other equivalent hydraulic barrier is sufficient to prevent erosion and scour.
i) To provide an indicator that the pervious pavement system has failed or needs maintenance, the system shall be designed to allow a minimum ponding depth of one (1) inch and a maximum ponding depth of two (2) inches prior to down-gradient discharge with the exception of pervious walks and bicycle paths. Additional details are provided in **Attachment G.** The permitted construction plans shall delineate the areas of pervious pavement that may be subject to nuisance ponding.
j) The pervious pavement system must be designed to have an overflow at the nuisance ponding elevation to the down-gradient stormwater treatment or attenuation system or outfall (see **Attachment G**).
k) Runoff from adjacent landscaped areas must NOT be directed onto pervious pavement system areas unless the Applicant demonstrates that the offsite areas that drain onto the pervious pavement will not increase sediment, silt, sand, or organic debris that increases the potential for clogging the pervious pavement. The design must reduce the likelihood of silts and sands from plugging the pavement void spaces.
l) With the exception of pervious walks and bicycle paths, the installation of Embedded Ring Infiltrometer Kit (ERIK) is required (see **Attachment G**). A minimum one (1) ERIK in-situ Infiltrometer will be required for each section of

pervious pavement installed. For larger sections, a minimum of two (2) in-situ ERIK Infiltrometer per acre of pervious pavement will be required. ERIK Infiltrometer shall not be placed at locations where subsequent testing may produce non-representative conclusions regarding the hydraulic function of the pervious pavement system. The location of the ERIK Infiltrometer shall be shown on the construction plans or other supporting sketches or drawings for the project.

m) Documentation of ERIK Infiltrometer construction, and post-construction testing, shall be required with submittal of the construction completion certification. Test results shall be provided in report form, certified by the appropriate Florida Registered Professional. The construction completion certification shall not be accepted if the vertical hydraulic conductivity is less than 2.0 inches per hour or is less than the permitted design percolation rate in any of the required ERIK Infiltrometer.

n) For proper maintenance of most pervious pavement systems, periodic vacuum sweeping is recommended. If ERIK tests indicate a vertical hydraulic conductivity rate less than 2.0 inches per hour, or is less than the permitted design percolation rate, or when nuisance ponding occurs, vacuum sweeping will be required. Vacuum sweeping also will be required for areas that are subject to wind transported soils (near sand dunes or other coastal areas) or other conditions where excessive soil or other debris deposition is expected to occur (from adjacent landscaping mulch and leaf litter, from areas with high leaf fall, fugitive sands and limerock fines from adjacent construction sites). Vacuum sweeping will be required annually.

o) The entrances to pervious pavement areas shall be posted by signs to inform users they are entering a pervious pavement area and that any vehicles with heavy wheel loads or with muddy tires should not enter.

6.8.2 Inspection, Operation and Maintenance

Maintenance issues associated with pervious pavements are related to clogging of the porous surfaces which reduces or prevents infiltration thereby slowing recovery of the stormwater treatment volume and often resulting in standing water and the designed nuisance flooding.

To determine if the pervious pavement is properly functioning or whether it needs maintenance requires that either an inspection be within 72 hours of a storm and that the ERIK devices be used to test the infiltration rate as specified below.

a) Inspection items:

- Inspect pervious pavement for storage volume recovery within the permitted time, generally less than 72 hours. Determine if nuisance flooding is occurring in those areas of the parking lot that were designed to flood if the pervious pavement was failing. Nuisance flooding indicates that the required treatment volume is not infiltrating because of a reduction of the infiltration rate and a need to restore system permeability

- Use the ERIK Infiltrometer at least once every two (2) years to test if the vertical hydraulic conductivity is less than 2.0 inches per hour or is less than the permitted design percolation rate in any of the required ERIK Infiltrometer. If any of the ERIK Infiltrometer have rates less than the permitted rate, maintenance activities shall be undertaken to restore the permeability of the pervious pavement. The results of the ERIK Infiltrometer testing shall be submitted to the City.
- Inspect all edge constraints and overflow areas to determine if any erosion is occurring and repair as needed.

d) Maintenance activities to prolong service life:

- Vacuum sweeping will be conducted annually and whenever the vertical hydraulic conductivity is less than 2.0 inches per hour or is less than the permitted design percolation rate in any of the required ERIK Infiltrometer. Vacuum sweeping will be done on an as-needed basis on pervious pavements located in areas that are subject to wind transported soils (near sand dunes or other coastal areas) or other conditions where excessive soil or other debris deposition is expected to occur (from adjacent landscaping mulch and leaf litter, from areas with high leaf fall, fugitive sands and limerock fines from adjacent construction sites, etc.).
- A remediation plan shall be submitted to the City should vacuum sweeping fail to improve the vertical hydraulic conductivity to a rate greater than 2.0 inches per hour, or equal to or greater than the permitted design percolation rate, or resolve the nuisance ponding. The remediation plan shall be prepared and submitted to the City’s compliance staff for review and approval.
- Repair erosion near edge constraints or overflows and ensure that the contributing drainage area is stabilized and not a source of sediments.

6.9 Retention Pond

Retention basins provide numerous benefits, including reducing stormwater volume, which reduces the average annual pollutant loading that may be discharged from the system. Additionally, many stormwater pollutants such as suspended solids, oxygen demanding materials, heavy metals, bacteria, some varieties of pesticides, and nutrients are removed as runoff percolates through the soil profile.

Soil permeability and water table conditions must be such that the retention basins can percolate the required treatment runoff volume within a specified time following a storm event. After drawdown has been completed, the basin does not hold any water, thus the system is normally “dry.” Unlike detention basins, the treatment volume for retention systems is not discharged to surface waters. **Figure 6-20** shows a typical cross-section of a “dry” retention pond. Retention basins shall be designed in accordance with the following design and performance criteria. Examples of Retention ponds are illustrated in **Figure 6-21** and **Figure 6-22**.

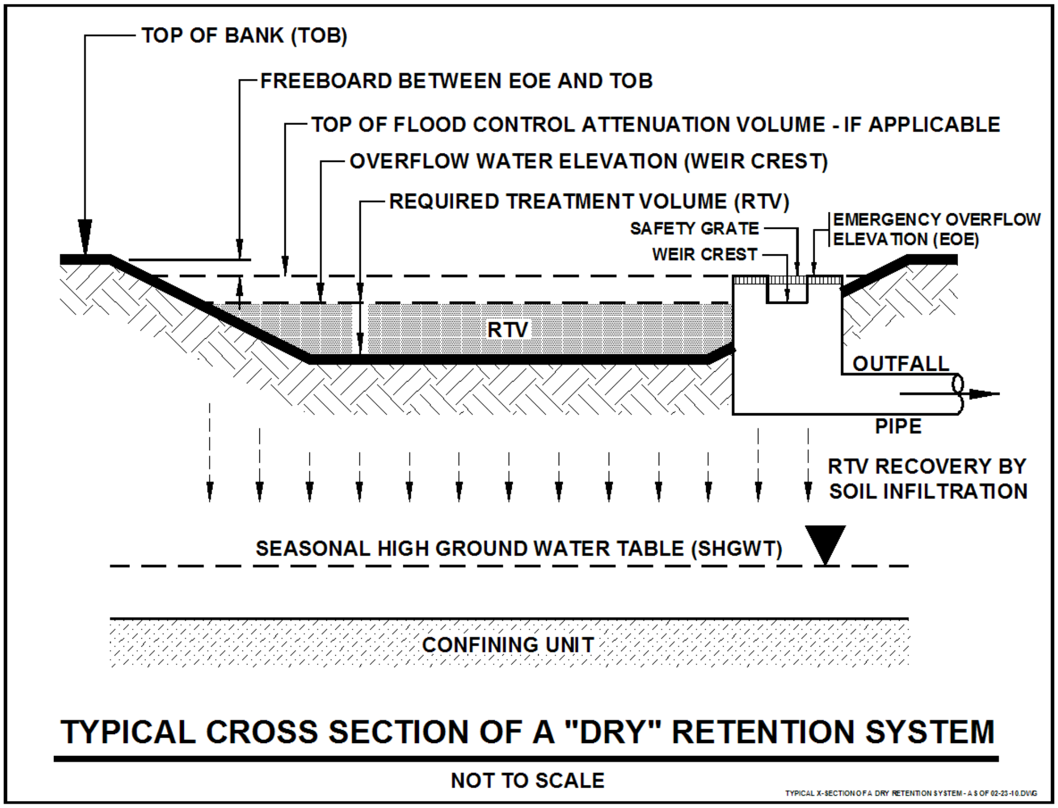

Figure 6-20 – Typical Cross-Section of a “DRY” Retention Pond

Figure 6-21 – Typical Dry Retention Pond

Figure 6-22 – Doral Glades Park Stomwater Wet Retention Pond

6.9.1 Design Criteria

a) The retention basin must recover the required treatment volume of stormwater within 72 hours, with a safety factor of two, assuming average Antecedent Runoff Condition (ARC 2).
b) The seasonal high ground water table shall be at least one foot beneath the of the retention basin unless the applicant demonstrates, based on plans, test results, calculations or other information, that an alternative design is appropriate for the specific site conditions.
c) The retention basin sides and bottom shall be stabilized with permanent vegetative cover, some other pervious material, or other methods acceptable to the City that will prevent erosion and sedimentation.
d) Retention basins shall not be constructed within 50 feet of a public or private potable water supply well.

6.9.2 Inspections, Operation and Maintenance

Maintenance issues associated with retention basins are related to clogging of the porous soils, which reduces or prevents infiltration thereby slowing recovery of the stormwater treatment volume and often resulting in standing water. Sedimentation can cause clogging and resulting sealing of the bottom or side slope soils. It can also occur from excessive loading of oils and greases or from excessive algal or microorganism growth. Standing water within a retention basin can also result from an elevated high water table or from ground water mounding, both of which can present long term operational issues that may require redesign of the system.

To determine if an infiltration system is properly functioning or whether it needs maintenance requires that an inspection be done within 72 hours after a storm. The inspection should determine if the retention basin is recovering its storage volume within its permitted time frames, generally 24 to 72 hours after a storm. If this is not occurring and there is standing water, then the cause must be determined and actions undertaken beginning with those specified in the system's Operation and Maintenance Plan.

e) Inspection items:

- Inspect basin for storage volume recovery within the permitted time, generally less than 72 hours. Failure to percolate the required treatment volumes indicates reduction of the infiltration rate and a need to restore system permeability.
- Inspect and monitor sediment accumulation on the basin bottom or inflow to prevent clogging of the retention basin or the inflow pipes.
- Inspect vegetation of bottom and side slopes to ensure it is healthy, maintaining coverage, and that no erosion is occurring within the retention basin.
- Inspect inflow and outflow structures, trash racks, and other system components for accumulation of debris and trash that would cause clogging and adversely impact operation of the retention basin.
- Inspect the retention basin for potential mosquito breeding areas such as where standing water occurs after 72 hours or where cattails or other invasive vegetation becomes established.

f) Maintenance activities to prolong service life:

- If needed, restore the infiltration capacity of the retention basin so that it meets the permitted recovery time for the required treatment volume.
- Remove accumulated sediment from retention basin bottom and inflow and outflow pipes and dispose of properly. Please note that stormwater sediment disposal may be regulated under Chapter 62-701, F.A.C). Sediment removal should be done when the system is dry and when the sediments are cracking.
- Remove trash and debris inflow and outflow structures, trash racks, and other system components to prevent clogging or impeding flow.
- Maintain healthy vegetative cover to prevent erosion in the basin bottom, side slopes or around inflow and outflow structures. Vegetation roots also help to maintain soil permeability. Grass needs to be mowed and grass clippings removed from the basin to reduce internal nutrient loadings.
- Eliminate mosquito breeding habitats.
- Ensure that the contributing drainage area is stabilized and not a source of sediments.

6.10 Parking Stormwater Chambers

Stormwater Chambers are used as underground infiltration or retention/detention systems in replacement of swales, ponds, concrete structures or pipe and stone installations. They are installed in trench or bed configurations according to site restrictions or client preference. For commercial applications, the placement of stormwater management systems beneath parking areas allows for further site development without sacrificing land area. Since retail development is often directly related to the number of parking spaces available, sub-surface installation of stormwater chambers maximizes land use and capability of additional parking spaces. **Figure 6-23** shows a typical cross-section of a parking stormwater chamber. Examples of these are illustrated in **Figure 6-24**.

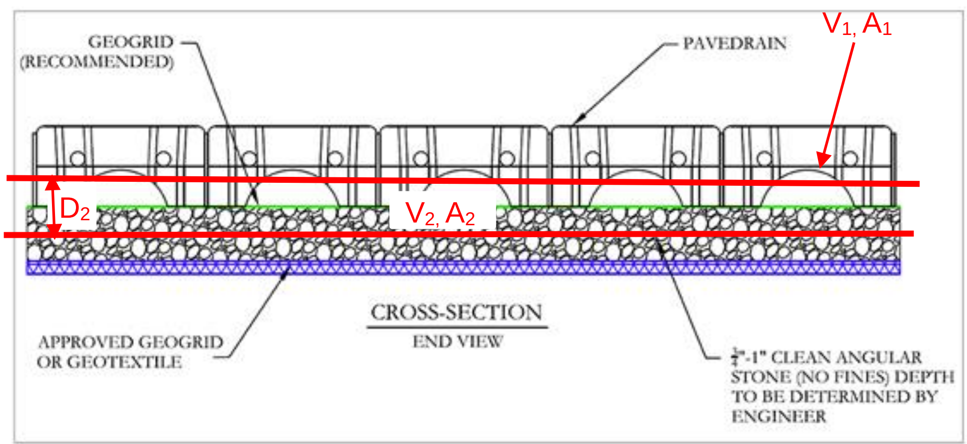

Figure 6-23 – Parking Stormwater Chambers Cross Section

Figure 6-24 – Stormwater Chambers

6.10.1 Design Criteria

Stormwater chamber systems consist of parallel rows of open-bottom, perforated plastic chambers (half pipes) surrounded by stone aggregate. The void ratio is maximized in the storage chambers and, when full, the void space in the gravel also provides stormwater storage. As proprietary technologies, stormwater chamber designs are developed and modified on a regular basis, and should be installed according to manufacturers' specifications. Stormwater chambers are intended to be used as infiltration practices where site conditions allow.

6.10.2 Inspections, Operation and Maintenance

Underground systems are primarily designed to function similar to surface basins at locations where usable space and real estate costs come at a premium. Thus, they're commonly built beneath parking lots and other solid-surfaces.

Generally, underground stormwater systems offer either retention or detention functions, and can help ensure the water quality of the runoff they release to sewers, waterways, or the ground. They are often made of high-density, polyethylene infiltration chambers, but there are many material variations in use. In fact, there are so many options for this type of stormwater system on the market that there's no one-size-fits-all maintenance procedure.

As with surface basins, the size and location of your underground system will dictate the frequency of the inspection and maintenance requirements. For instance, a system built under a large commercial parking lot will be exposed to more trash and debris than a smaller one meant for residential use, and will therefore require more frequent attention.

For underground retention systems with significant sediment accumulation, the use of a high-powered vacuum truck to extract accumulated sediment is the standard recourse. With underground detention systems, however, the low-flow orifice will be the key point in the system's maintenance, since it regulates stormwater outflows. In such a system, the low-flow orifice needs to be kept clear of any trash, sediment, or debris.

7.0 LID PERFORMANCE AND RETENTION CREDITS

The following subsections describe the performance credit available for each structural LID BMP implemented for development sites. To determine the LID BMP retention credits for the reduction of discharge runoff volume from the site, the sum of the total retention volume of storage provided by all the BMPs on the site and the total infiltration volume must be accounted for based on each BMP infiltration capacity.

Each structural LID BMP has a unique approach for determining the storage volume it provides. **Section 7.1 through 7.10** describes the approach for each structural LID BMP recommended for use within the City of Doral.

7.1 Bioretention Basins or Rain Gardens

Volume provided by Bioretention or Rain Garden BMPs is estimated by the following equations.

Equation 2 - Storage Volume of Bioretention Basin or Rain Gardens

$$V_{Bioretention} = V_1 + V_2 \text{ , } (ft^3)$$

Where,

$$V_1 = A_1 \; x \; D_1 \; x \; 0.75 \; (assumed \; 25\% \; vegetated \; cover), (ft^3)$$

$$V_2 = A_2 \; x \; D_2 \; x \; 0.50 \; \; (assumed \; void \; ratio), \; (ft^3)$$

Refer to **Figure 6-1** for a schematic of the equation parameters.

Infiltration provided by Bioretention or Rain Garden BMPs is estimated by the following equation.

Equation 3 - Infiltration Provided by Bioretention Basin or Rain Gardens

$$I_C = I_R \; x \; A_{Bioretention} \text{ , } \left(\frac{ft^3}{s/(ft \; of \; head)}\right)$$

Where,

$$A_{Bioretention} = \frac{V_{Bioretention}}{D_C}$$

Refer to **Figure 6-1** for a schematic of the equation parameters.

7.2 Tree Box Filters and Infiltration Planters

Volume provided by Tree Box Filter or Infiltration Planter BMPs is estimated by **Equation 4**.

Equation 4 - Storage Volume of Tree Box Filter or Infiltration Planter

$$V_{Tree\ Box} = V_1 + V_2 , (ft^3)$$

Where,

$$V_1 = A_1\ x\ D_1\ x\ 0.75\ (assumed\ 25\%\ vegetated\ cover), (ft^3)$$

$$V_2 = A_2\ x\ D_2\ x\ 0.50\ (assumed\ void\ ratio), (ft^3)$$

Figure 6-3 for a schematic of the equation parameters.

Infiltration provided by Tree Box Filter or Infiltration Planter BMPs is estimated by the following equation.

Equation 5 - Infiltration Provided by Tree Box Filter or Infiltration Planter

$$I_C = I_R\ x\ A_I, \left(\frac{ft^3}{s/(ft\ of\ head)}\right)$$

Refer to **Figure 6-3** for a schematic of the equation parameters.

7.3 Vegetated Swales

Volume provided by Vegetated Swale BMPs is estimated by the following equations.

Equation 6 - Storage Volume of Vegetated Swales

$$V_{Swale} = V_1 + V_2 , (ft^3)$$

Where,

$$V_1 = A_1\ x\ D_1\ x\ 0.75\ (assumed\ 25\%\ vegetated\ cover), (ft^3)$$

$$V_2 = A_2\ x\ D_2 , (ft^3)$$

Infiltration provided by Vegetated Swale BMPs is estimated by the following equation. Refer to **Figure 6-6** for a schematic of the equation parameters.

Equation 7 - Infiltration Provided by Vegetated Swales

$$I_C = I_R\ x\ A_{Swale}, \left(\frac{ft^3}{s\ (ft\ of\ head)}\right)$$

Where,

$$A_{Swale} = \frac{V_{Swale}}{D_C}$$

7.4 Filter Strips or Vegetated Buffers

The volume associated with the Filter Strip or Vegetated Buffer BMPs is estimated by the following equation

Equation 8 - Storage Volume of Filter Strips or Vegetated Buffers

$$V_{Buffer} = A_I \ x \ D_I \ x \left(\frac{1ft}{12in}\right), (ft^3)$$

Where,

$$A_I \ = Area\ of\ Infiltration, (ft^2)$$

$$D_I \ = 1\ in, Filter\ Strips\ or\ Vegetated\ Buffers\ with\ slopes\ < 1:10$$

$$D_I \ = \frac{1}{2}\ in, Filter\ Strips\ or\ Vegetated\ Buffers\ with\ slopes\ \geq\ 1:10\ and\ \leq 1:6$$

No volume credit will be accounted for filter strips or vegetated buffers with less than 25 ft wide or with a slope greater than 1:6 because this extraction is already accounted for in the ½ inch to 1 inch in **Equation 8**. Refer to **Figure 6-8** for a schematic of the equation parameters.

7.5 Infiltration Trench

Volume provided by Infiltration Trench BMPs is estimated by the following equations.

Equation 9 - Storage Volume of Infiltration Trench

$$V_{Infiltration\ Trench} \ = V_1, (ft^3)$$

Where,

$$V_1 = A_1\ x\ D_1\ x\ 0.50\ (assumed\ void\ ratio), (ft^3)$$

Infiltration provided by Infiltration Trench BMPs is estimated by the following equation. Refer to **Figure 6-10** for a schematic of the equation parameters.

Equation 10 - Infiltration Provided by Infiltration Trench

$$I_C = I_R\ x\ A_I, \left(\frac{ft^3}{s\ (ft\ of\ head)}\right)$$

7.6 Exfiltration Trench or French Drains

Volume provided by Exfiltration Trench or French Drain BMPs is estimated by the following equation.

Equation 11 - Storage Volume Provided by Exfiltration Trench

$$V_{Exfiltration\,Trench} = A_1\ x\ 3.28\ in\ x\ \left(\frac{1ft}{12in}\right), (ft^3)$$

Where,

$$A_1 = Project\ Site\ Area\ Captured\ by\ the\ Exfiltration\ Trench\ , (ft^2)$$

Refer to **Figure 6-12** and **Figure 7-1** for a schematic of the equation parameters.

Drainage trenches in a given system have the ability to exfiltrate, or extract, up to 3.28 inches of the total rainfall depth produced by a design rainfall event over the area contributing runoff. This is an accepted practice by DRER and the SFWMD. The project area shown in **Figure 7-1**, the total project area is contributing to an exfiltration trench.

Figure 7-1 - Area Attributed to an Exfiltration Trench Length

The 3.28-inch parameter in **Equation 11** is the amount of rainfall produced from 5-year, 1-hour storm event and the maximum extraction amount allowed by SFWMD. No additional exfiltration credit is accounted for the drainage trench systems because the volume is accounted for by the 3.28 inch.

Infiltration provided by Exfiltration Trench BMPs is estimated by **Equation 12**.

Equation 12 - Infiltration Provided by Exfiltration Trench

$$I_C = I_R \, x \, A_{Exfiltration} \, , \left(\frac{ft^3}{s\,(ft\,of\,head)}\right)$$

Where,

$$A_{Exfiltration} = \frac{V_{Exfiltration\,Trench}}{D_C}$$

7.7 Green Roofs or Rain Barrels/Cisterns

Volume provided by the Rain Barrel/Cistern BMP is estimated by the following equation.

Equation 13 - Storage Volume Provided by Green Roofs and Cisterns

$$V_{Rain\,Barrels}\,(ft^3) = Total\,Volume\,of\,Rain\,Barrel\,or\,Cistern,\,(ft^3)$$

There is no infiltration extraction associated with this BMP. Refer to **Figure 6-12** and **Figure 7-1** for a schematic of the equation parameters.

7.8 Permeable Pavements

Volume provided by Permeable Paver BMPs is estimated by the following equations.

Equation 14 - Storage Volume of Permeable Pavement

$$V_{Permeable\,Pavement} = V_1\,,(ft^3)$$

Where,

$$V_1 = D_1\,x\,A_1\,x\,0.50\,(assumed\,void\,ratio)\,,\,(ft^3)$$

Infiltration provided by Permeable Paver BMPs is estimated by the following equation.

Equation 15 - Infiltration Provided by Permeable Pavement

$$I_C = I_R\,x\,A_I\,,\left(\frac{ft^3}{s\,(ft\,of\,head)}\right)$$

Refer to **Figure 6-18** for a schematic of the equation parameters.

7.9 Retention Ponds

Volume provided by Retention Pond BMPs is estimated by the following equations.

Equation 16 - Storage Volume of Retention Ponds

$$V_{Retention\ Pond} = V_1\ , (ft^3)$$

Where,

$$V_1 = Physical\ Volume\ of\ Retention\ Pond, (ft^3)$$

Infiltration provided by Retention Pond BMPs is estimated by the following equation. Refer to **Figure 6-20** for a schematic of the equation parameters.

Equation 17 - Infiltration Provided by Retention Ponds

$$I_C = I_R\ x\ A_{Retention\ Pond}\ , \left(\frac{ft^3}{s\ (ft\ of\ head)}\right)$$

Where,

$$A_{Retention\ Pond} = \frac{V_{Retention\ Pond}}{D_C}$$

7.10 Parking Stormwater Chambers

Volume provided by parking stormwater chamber BMPs is estimated by the following equations. Refer to **Figure 6-23** for a schematic of the equation parameters.

Equation 18 - Storage Volume of Parking Stormwater Chambers

$$V_{Chamber} = V_1 + V_2\ , (ft^3)$$

Where,

$$V_1 = (Total\ Volume\ of\ Chamber\ ), (ft^3)$$

$$V_2 = A_2\ x\ D_2\ x\ 0.50\ (assumed\ void\ ratio), (ft^3)$$

Infiltration provided by Parking Stormwater Chamber BMPs is estimated by **Equation 19**.

Equation 19 - Infiltration Provided by Parking Stormwater Chambers

$$I_C = I_R\ x\ A_{Chamber}\ , \left(\frac{ft^3}{s\ (ft\ of\ head)}\right)$$

Where,

$$A_{Chamber} = \frac{V_{Chamber}}{D_C}$$

7.11 Site Credits

The following credits are established to account for evapotranspiration and irrigation:

1. Evapotranspiration (ET) represents the loss of water from the soil through the combined process of evaporation (from soil and plant surfaces) and plant transpiration. Daily evapotranspiration rates for South Florida are provided in **Table 7-1**.

Table 7-1 – Daily Evapotranspiration Rates for South Florida

Month	South Florida (in/day)
January	0.1
February	0.13
March	0.16
April	0.19
May	0.19
June	0.18
July	0.18
August	0.17
September	0.15
October	0.14
November	0.12
December	0.1

Source: Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 1994.

Based on this information, the annual average ET volume credit is 0.15 inch per day. Therefore, the total annual ET volume (V_{ET}) credit would be computed as:

Equation 20 – Volume of evapotranspiration

$$V_{ET} = 0.15 \frac{in}{day}\ x\ 365\ days\ x\ Site\ Vegetated\ area\ (ft^2)\ x\ \left(\frac{1ft}{12in}\right), (ft^3)$$

2. The frequency of irrigation varies based on each sties vegetation, rainfall amount, soil conditions, and drainage characteristics. The quantity of irrigation water demand will vary seasonally, and is greater on sites with more compacted soils and greater direct sunlight. As an example of irrigation water demand, the monthly irrigation water demand used for common varieties of turf-grass in Miami-Dade County are provided **Table 7-2**. The calculation of demand took into account monthly precipitation, average temperature, and other geological characteristics of the study area.

Table 7-2 – Monthly Irrigation Demand for Turf-grass

Month	Miami (in/month)
January	2.09
February	1.99
March	3.12
April	3.24
May	3.05
June	2.69
July	4.32
August	4.75
September	2.74
October	1.13
November	2.85
December	2.61

Source: Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 2011

Based on this information, the annual irrigation volume credit is 2.88 inches per month. Therefore, the total annual irrigation volume (V_{IR}) credit is computed using **Equation 21**.

Equation 21 – Volume of irrigation water demand

$$V_{IR} = 2.88\frac{in}{month}\ x\ 12\frac{months}{year}\ x\ Site\ Irrigated\ Area\ (ft^2)\ x\left(\frac{1ft}{12in}\right), (ft^3)$$

Irrigation volume credits are accounted for in areas irrigated from runoff volume retained within storage LID BMPs. Irrigation credits will not be established for well or potable water irrigation sources.

8.0 APPROACH TO ESTABLISH EXCESS ANNUAL RUNOFF VOLUME

As part of the Stormwater Management Master Plan development for the SFWMD C-4 and C-6 Basins, DRER developed an average annual rainfall distribution (Miami FS) using the rainfall measure at the rainfall gauge from the Miami Field Station from January 1, 2012 through December 31, 2012. The total average rainfall for this period of record was 60.11 inches. The rainfall distribution is shown in **Figure 8-1**. The daily rainfall distribution matrix for this average annual rainfall event is included in **Attachment F**. This average rainfall event was also implemented as part of the City of Doral Stormwater Master Plan update in 2014 to estimate annual pollutant loading. The approach described herein assumes the adoption of this average annual rainfall event by the City of Doral for LID hydrologic and hydraulic analysis of development sites.

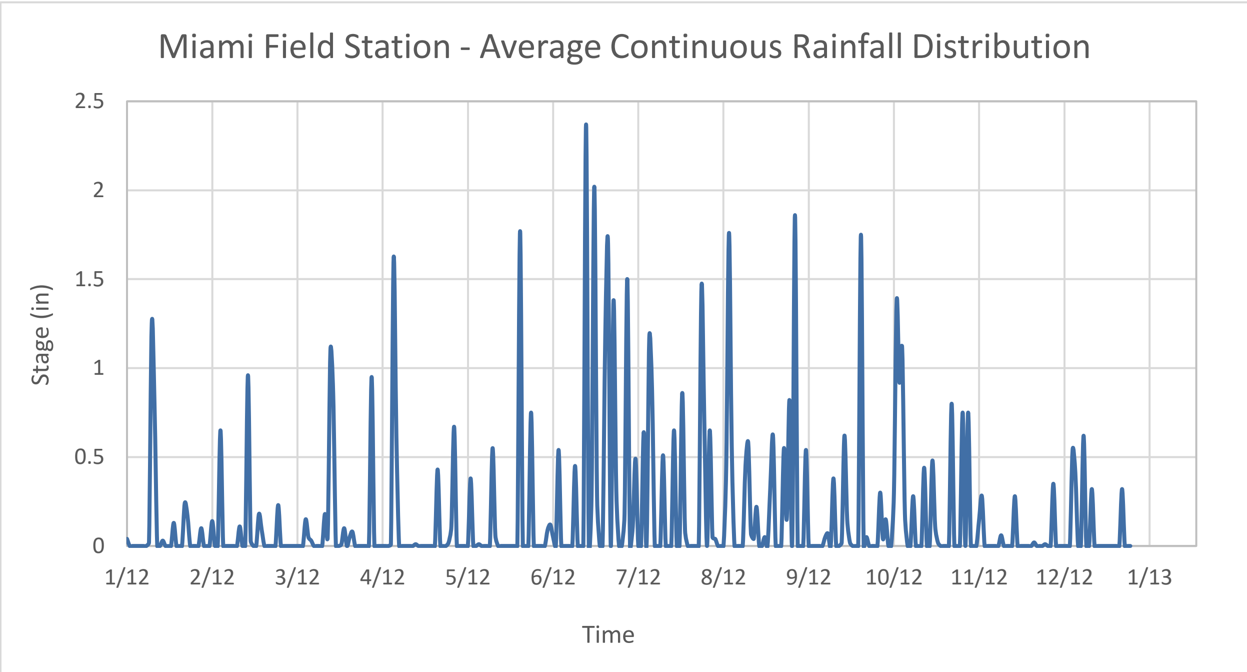

Figure 8-1 – Miami Field Station Average Continuous Rainfall Distribution

Quantification of the excess annual runoff from development sites will use hydrological/hydraulic computer modeling software to simulate routing the average annual rainfall distribution through the pre-development site and post-development site. The site parameters described in **Section 5.1** and **Section 5.2** are used to represent the site-specific conditions in the models for quantifying the excess runoff.

The models are constructed using basins, nodes, and links to represent the hydraulic and hydrologic data of the site. Nodes typically represent junctions in the model, runoff storage, and points of discharge leaving the site. Links represent the conveyance of water between nodes including overland flow, flow through traditional pipes, and infiltration.

An example of a node-link schematic for a typical model of a development site is shown in **Figure 8-2.** The site in the example is represented using a single B01 drainage basin with runoff discharging to the S01 onsite node. The parameters provided in the box callout for the drainage basin are the design parameters determined for the characteristics of the site. The OFFSITE node represents the offsite area receiving excess runoff from the site, typically the City right-of-way for sites in Doral. The groundwater table, receiving infiltration from the site is represented using the triangular Ground model node.

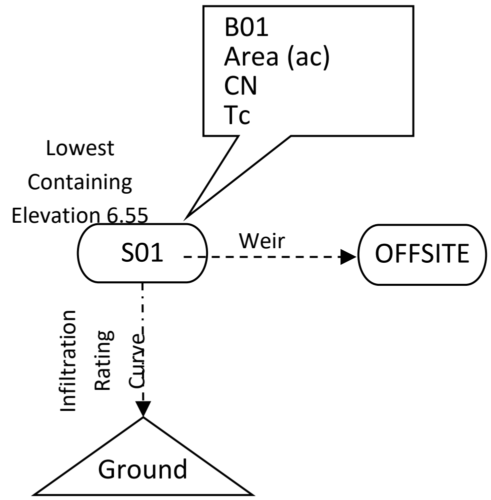

Figure 8-2 – Node-Link Schematic for a Model of a Development Site

It is recommended to use the stage-area relationship for the model nodes and to represent the treatment provided by structural LID BMPs. The representative area of the treatment provided by the structural LID BMP is determined by dividing the calculated LID BMP storage volume(s), using the equations provided in **Section 7.1 through 7.10**, and dividing by the containing depth, **Equation 22.**

Equation 22 - Representative BMP Area

$$A_{R.BMP} = \frac{\sum V_{BMP}}{D_C}$$

Where,

- $A_{R.BMP}$ = Representative BMP area (acres)
- $\sum V_{BMP}$ = Sum of the storage volume(s) calculated for each BMP with the approach outlined in **Section 7.1 through 7.10** (acre-feet)
- D_C = Containing Depth (feet)

For the stage-area relationship, the stages will range from the average October elevation at the site to the highest site containing elevation as illustrated in **Figure 8-3**.

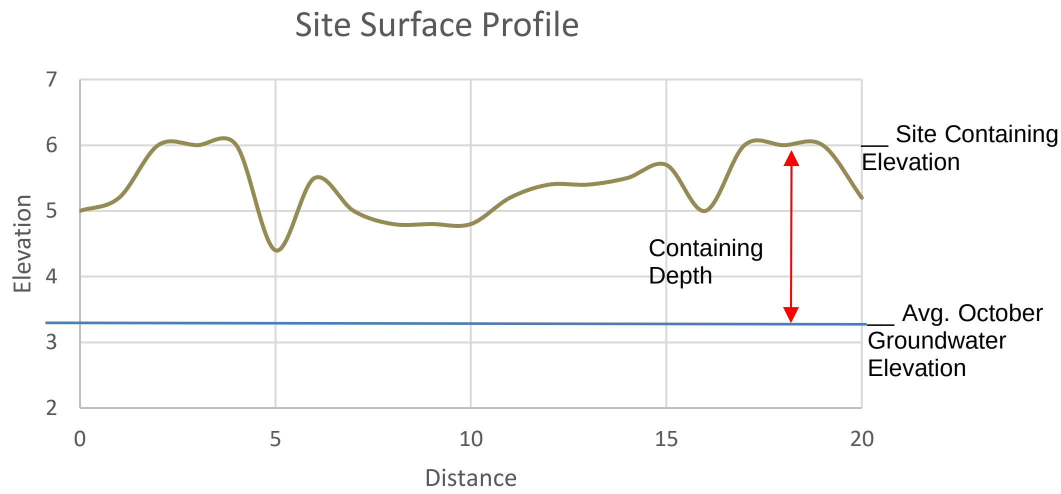

Figure 8-3 – Stage-Area Relationship

The amount of infiltration credit for LID BMPs discharging to the groundwater table will be simulated with a rating curve link in the model, using the sum of the infiltration capacity of all LID BMPs in cubic feet per second per foot of head. The infiltration capacity is calculated using **Equation 23**.

Equation 23 - Sum of Infiltration Capacity

$$\sum I_C = I_R \; x \; A_I$$

Where,

- $\sum I_C$ = Sum of Infiltration Capacity (cubic feet per second per foot of head)
- I_R = Infiltration Rate (feet per second per foot of head) *
- A_I = LID BMP Infiltration Area (square feet)

*I_R is estimated by performed Double-ring infiltration tests on site. It is recommended that that a minimum of one (1) Double-ring test per five (5) acres of existing or proposed open area.

The process used for development of the model representing the pre-development site and the model specific parameters needed depends on the pre-development site classification.

For the City of Doral, pre-development conditions will be classified as one of the following:

1. Natural, undeveloped site
2. Site with existing development

8.1 Natural, Undeveloped Pre-Development Site

A natural, undeveloped pre-development site is an area with no existing infrastructure including stormwater control infrastructure. Based on the sources cited in **Section 5.2**,the steps recommended for determining the pre-development excess annual runoff volume from a natural, undeveloped pre-development sites are as follows:

1. Develop the rainfall-runoff relationship for the catchment, or model node, using topographic and geologic data from the project site. Linear storage can be applied to most natural, undeveloped sites. It is recommended to use stage-area for the site storage representation in the model node.
2. The initial condition for each node should set as the lowest topographic elevation or the average October groundwater elevation as established by DRER for sites with open water or lakes. The average October groundwater elevation for the City of Doral ranges from 1.43 to 2.43 feet relative to the North American Vertical Datum of 1988 (ft-NAVD). The elevation conversion in the City of Doral is the National Geodetic Vertical Datum (NGVD) minus 1.57 to obtain NAVD.
3. Use the method described in Section 2-1 of TR 55 to establish the CN of the site based on the surface-to-groundwater depth relationship (see **Table 5-1**).
4. Determine the Tc for each catchment. The approach to estimate Tc is outlined in Chapter 3 of TR 55 (see **Section 5.2**).
5. Establish the available infiltration rate per foot of head based on information obtained from a Double-ring infiltration test performed at the site. The amount of infiltration will be simulated in the model by a rating curve link using the infiltration rate as a function of available hydraulic head.
6. Establish the available annual evapotranspiration volume. **Section 7.11** describes the approach for estimating the annual evapotranspiration volume.
7. Estimate the perimeter length of the lowest site elevation where runoff would be discharged offsite via overland flow (typically the City's right-of-way within the City of Doral). This will be simulated in the model by using a vertical weir link from the site model node to the Offsite model node.
8. Route Miami FS depicted in **Figure 8-1, Section 5.2**. The total average yearly rainfall for the period of record was 60.11 inches.

The total estimated pre-development annual runoff volume discharged offsite from the existing site to the City's right-of-way is determined by subtracting the total annual evapotranspiration volume from the total annual runoff volume discharged to the offsite model node.

8.2 Pre-Development Site with Existing Development

Sites that have infrastructure are classified as a pre-development site with existing development. This includes sites in which the existing infrastructure will be modified or replaced. The establishment of the excess annual runoff volume from the pre-development site needs to take into account the existing stormwater BMPs, and the existing irrigation use for vegetated areas. The steps to develop a pre-development site condition model of a site with existing development are as follows:

1. Develop a stage-storage node based on the topographic and geologic information for the project site. The storage node is most commonly represented in the model using a stage-area relationship.
2. If the site has existing LID BMPs, determine the retention volume available for each BMP by implementing the procedures described for each applicable LID BMP in **Section 7.0**. For existing LID BMPs using soil storage, reduce the retention volume by 50% to account for media clogging in the exfiltration systems and reduced system performance. The available BMP volume is then implemented as a stage-area relationship in the model.
    a. The area of the BMP is the total BMP retention volume divided by the total depth of the BMP.
    b. The stages for the structure will range from the average October elevation to the highest elevation of the site.

    This stage-area relationship is then added to the site model to develop and overall site stage-area relationship.
3. The initial condition for the stage-area node should be set as the lowest site elevation or the average October groundwater elevation as established by DRER for sites with open water, lakes or existing LID BMPs (whichever is the highest). The average October groundwater elevation for the City of Doral ranges from 1.43 to 2.43 ft NAVD.
4. Use the approach described in Section 2-1 of TR 55, to establish the CN of the site based on the surface-to-groundwater depth relationship (see **Table 5-1**).
5. Determine the Tc for each catchment. The approach to estimate Tc is outlined in Chapter 3 of TR 55 (see **Section 5.2**).
6. Establish the available infiltration rate per foot of head based on information obtained from a Double-ring infiltration test for all open areas and existing LID BMPs that promote infiltration. For existing infiltration systems reduce the infiltration capacity by 50% to account for reduced system performance. The amount of infiltration will be implemented in the model using a rating curve link and the infiltration rate as a function of available hydraulic head.
7. Establish the annual irrigation volume based on the vegetation areas of the site that are currently irrigated from runoff retained within the existing LID BMPs. Irrigation credits will not be established for well or potable water irrigation sources. **Section 7.11**. describes the approach for estimating annual irrigation volume credit for the site.
8. Establish available annual evapotranspiration volume credit for open vegetated areas. **Section 7.11**. describes the approach for estimating annual evapotranspiration volume credit for the site.
9. For a site with no outfall to a canal or receiving water body, estimate the perimeter length of the lowest site elevation where runoff would be discharged via overland flow to an offsite area (typically the City's right-of-way for sites in Doral). This will be simulated in the model by using a vertical weir link from the Site Node to the OFFSITE node, as shown in **Figure 8-2**. For sites with outfall(s) or control

structure(s), include the outfall(s) and control structure(s) as an additional link(s) discharging to the OFFSITE node.

10. Route Miami FS total average annual rainfall distribution depicted on **Figure 8-1** (see **Section 5.2**). The total average yearly rainfall for the period of record was 60.11 inches and this will be used to evaluate pre versus post conditions.

An example of a node-link schematic for a model representing a pre-development site with existing development is shown **Figure 8-4**.

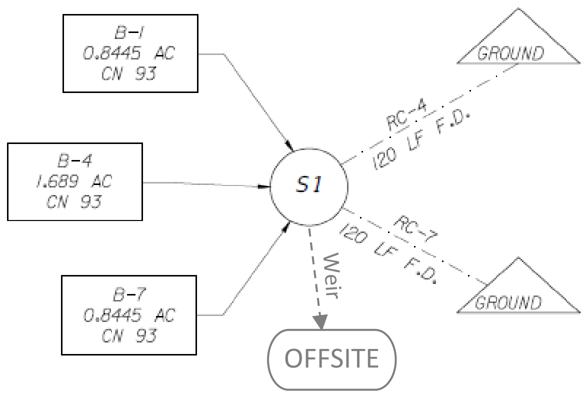

Figure 8-4 – Node-Link Schematic for Sites with Pre- Developments Condition Model for a site with Existing Infrastructure

In this example, the site has three French drains that are represented in the schematic by the three basin box callouts. The total length of French drain and total infiltration is implemented using rating curves represented in the schematic by RC-4 and RC-7. The total estimated pre-development annual runoff volume discharged offsite from the existing site is determined by subtracting the total annual evapotranspiration and irrigation volume from the total annual runoff volume discharged to the OFFSITE node.

8.3 Post-Development Conditions

For post-development sites the approach is very similar to pre-developed sites. The excess annual runoff is determined by routing the annual average rainfall distribution included in **Attachment E** through the available onsite storage, including the additional storage provided by the LID BMPs implemented, while accounting for available infiltration, evapotranspiration and irrigation. To develop post-development sites condition model:

1. Develop a stage-storage node based on the proposed site grading conditions. The storage should be represented in the model as a stage-area relationship.
2. For the proposed structural LID BMPs, determine the available BMP retention volume by implementing the procedures outlined in **Section 7.0**. The volume is then represented as a stage-area relationship in the model. The area is determined by dividing the total BMP retention volume by the total depth. The stages will then range from the average October elevation for the site to the highest site containing

elevation. This stage-area relationship is then added to the site storage defined above to develop and overall site stage-area relationship.

3. The initial condition for the stage-area node should set as average October groundwater elevation as established by DRER for sites with open water, lakes or existing LID BMPs. The average October groundwater elevation for the City of Doral ranges from 1.43 to 2.43 feet relative to the North American Vertical Datum of 1988 (ft-NAVD).
4. Use the SFWMD method to establish the CN of a site based on a surface-to-groundwater depth relationship (see **Section 5.2**).
5. The approach to estimate Tc is outlined in Chapter 3 of TR 55 (see **Section 5.2**).
6. Establish the available infiltration rate per foot of head based on information obtained from a Double-ring infiltration test and procedure outlined in **Section 5** for all open areas and proposed LID BMPs that promote infiltration. The amount of infiltration will be simulated in the model by developing rating curve link using the infiltration rate as a function of available hydraulic head.
7. Established annual irrigation volume based on site areas that will be irrigated from runoff volume retained within onsite LID BMPs. Irrigation credits will not be established for well or potable water irrigation sources. **Section 7** describes the approach for estimating annual irrigation volume credit for the site.
8. Establish available annual evapotranspiration volume credit for open vegetated areas. **Section 7** describes the approach for estimating annual evapotranspiration volume credit for the site.
9. For a site with no outfall to existing canal or receiving water body, estimate the perimeter length of the lowest proposed site elevation where runoff would be discharged via overland flow to an offsite area (typically the City's right-of-way). This will be simulated in the model by using a vertical weir link from the Site Node to the OFFSITE node. For sites with outfall(s) or control structure(s), include the outfall(s) and control structure(s) as an additional link(s) discharging to the OFFSITE node.
10. Example of a node-link schematic for sites with existing developments condition model is shown in **Figure 8-5.**Error! Reference source not found.
11. Route Miami FS total average annual rainfall distribution depicted on **Figure 8-1.** The total average yearly rainfall for the period of record was 60.11 inches and this will be used to evaluate pre- versus post conditions.

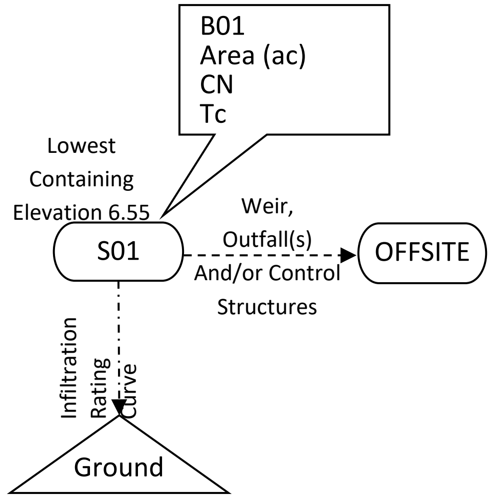

Figure 8-5 - Node-Link Schematic for Post Developments Condition Model

The total estimate post-development annual runoff volume discharged offsite from the existing site to the City's right-of-way is determined by subtracting the total annual evapotranspiration and irrigation volume from the total annual runoff volume discharged to the OFFSITE node.

9.0 SAMPLE APPLICATION

The intent of the sample application is to provide an example of applying the LID BMPs pre- versus post-development runoff volume approach outlined in this manual for the Doral area. For the following example, all the parameters were obtained using the processes outlined in the previous sections of this Master Plan. The average annual rainfall provided in **Attachment F** was the rainfall event used in this example.

9.1 Existing Conditions

The selected project site is the Proposed Doral Commons based on the plans prepared on January 20, 2014 and provided by the City of Doral. The site in existing conditions is an undeveloped natural site consisting primarily of vegetation and grass areas. The containing elevation varies greatly along the perimeter of the site with the lowest elevations along the back side of the property. A hydrologic/hydraulic model was developed using ICPR4 to quantify the pre-development annual offsite runoff volume of the natural site condition.

- Total Site Area = 22.06 Ac.
- Pervious Area = 22.06 Ac.
- Impervious Area = 0.00 Ac.
- Containing Elevation = 3.81 ft-NGVD

The following approach was implemented in setting up the pre-development ICPR model (see **Attachment H** for the Node-Link Schematic):

1. Develop a linear storage or stage-storage node for the site area:
   a. Node S1: stage-area node (22.06 acres)
   b. CN 94
   c. TC 60 minutes
   d. Initial condition set to 3.8-ft (Average October Groundwater Elevation)
2. DHW elevation is set to 3.8-ft NGVD
3. Infiltration rate per foot of head obtained from a double-ring test for all open areas (61.02 ft^3/s per ft-head).
   a. Develop a rating curve link using the infiltration rate as a function of available hydraulic head for all site area where infiltration is possible.
4. Vertical Weir was set up and the containment elevation to allow runoff to be discharged to the OFFSITE node:
   a. Weir back at elevation 3.81 ft

The total estimated pre-development annual runoff volume discharged offsite from the existing site to the City's right-of-way is determined by subtracting the total annual evapotranspiration volume from the total annual runoff volume discharged to the OFFSITE node. Refer to **Attachment H** for calculations and supporting information.

1. Total annual runoff received by OFFSITE Node: 108.8 ac-ft.

2. Annual evapotranspiration volume for open vegetated areas (22.06 Ac) is 100.6 ac-ft.
3. Total Runoff to City's right-of-way for Pre-Development Conditions: 8.2 ac-ft.

9.2 Proposed Condition

Under the post-development conditions, the Proposed Doral Commons site consists of multiple commercial buildings, large open parking lots with vegetated islands, a dry retention pond, and Exfiltration Trenches. The post-development site has approximately 20% of open areas remaining.

- Total Site Area = 22.06 Ac.
- Pervious Area = 4.41 Ac.
- Impervious Area = 17.65 Ac.
- Containing Elevation = 7.0 ft-NGVD

The following approach was implemented in setting up the pre-development ICPR model (see **Attachment H** for Node-Link Schematic):

1. Developed a stage-storage node based on the proposed site grading conditions.
    a. Node SITE: stage-area node
    b. CN 97
    c. TC 10 minutes
    d. Initial condition set to 3.8 ft-NGVD (Average October Groundwater Elevation)
2. For the proposed structural LID BMPs, determined the available BMP retention volume by implementing the procedures outlined in **Section 7.0**. The volume was then represented as a stage-area relationship in the model.
    a. Area (total BMP retention volume/total depth).
        i. Dry Retention Pond:1.30 Ac
        ii. Exfiltration Trenches: 0.35 Ac.
    b. Stages range (3.8 ft-NGVD to 7.0 ft-NGVD)
    c. This stage-area relationship for each BMP was combined and added to the overall site stage-area relationship.
3. DHW elevation is set to 3.8-ft NGVD
4. Infiltration rate per foot of head (procedure outlined in **Section 7.0**) for all open areas and proposed LID BMPs that promote infiltration (3.60 ft^3/s per ft-head).
5. Develop a rating curve link using the infiltration rate as a function of available hydraulic head. Vertical Weir was set up at the containing elevation.

The total estimated post-development annual runoff volume discharged offsite from the proposed site to the City's right-of-way is determined by subtracting the total annual evapotranspiration volume from the total annual runoff volume discharged to the OFFSITE node. Refer to **Attachment H** for calculations and supporting information.

1. Total annual runoff received by OFFSITE Node: 0.00 ac-ft

   a. No offsite runoff is shown as the Dry Retention Pond and Exfiltration Trenches captured the annual volume of runoff.
2. Annual evapotranspiration volume for open vegetated areas (4.41 Ac) is 20.1 ac-ft
3. Total Runoff to City's right-of-way for Post-Development Conditions: 0.0 ac-ft

The total reduction in runoff from the pre-development to post-development condition is 8.2 ac-ft. The LID BMPs (dry retention pond, open areas and exfiltration trenches implemented in this example are more than adequate to ensure the post-development site does not contribute more runoff volume than the pre-development site to the City's right-of-way on an annual basis.

In addition to the hydrologic volume and discharge benefits, the Doral Commons retention pond BMP contains vegetation that provides benefits of habitat for wildlife, shade, improved aesthetics, and heat island mitigation.

10.0THE CITY OF DORAL SOIL EROSION AND SEDIMENT CONTROL PRACTICES

The City of Doral participates as a co-permittee with Miami-Dade County in the National Pollution Discharge Elimination System (NPDES) program. The program is aimed at improving stormwater runoff water quality and control erosion from construction activities. The City of Doral must address specified activities and program compliance stated within the Annual Reports and NPDES permit conditions.

The permit conditions require the Building Department, Planning & Zoning Department, Public Works Department, and Code Compliance Department to enforce the following activities as part of the Construction Site Erosion and Sedimentation Control (construction activity means the act of developing or improving land that involves the disturbance of soils and includes clearing, grading, and excavation). The Florida Department of Environmental Protection (FDEP), which administers the NPDES permits in Florida for the US Environmental Protection Agency (EPA), has determined that demolition activities must also meet the definition of construction activity:

1. **Submission of Erosion & Sedimentation Control plan**: Applicants for new construction projects or substantial improvements (i.e., additions, pools, etc.) shall submit as part of the mandatory permit submittal documents of an erosion and sedimentation control plan for the development of the site.

2. **Best Management Practices (BMPs) for Erosion and Sedimentation Control:** Three (3) mandatory erosion and sedimentation control best management practices shall always be implemented at each development site. These are:
   a) Temporary Gravel Construction Entrance & Exit **(Figure 10-1)**
   b) Storm Drain Inlet Protection **(Figure 10-2)**
   c) Staked Turbidity Barrier or Silt Fence **(Figure 10-3)**

   NOTE: The Preceding three elements of the plan must be implemented at the development site, inspected and approved by the Chief Building Official or designated inspector prior to the acceptance of the first mandatory Florida Building Code inspection request.

3. **Compliance with Erosion and Sedimentation Control Plan:** Mandatory Florida Building Code inspections and inspection for erosion and sedimentation control shall be performed simultaneously with construction inspections. Failure to maintain Erosion and sedimentation control measures during the entire construction phase will result in a rejected inspection request and/or Code Compliance Department action to be treated as a violation of the City's Code or Ordinance by the Code Compliance Office.

Figure 10-1 – Temporary Gravel Construction Entrance & Exit (a)

Figure 10-2 – Storm Drain Inlet Protection (b)

Figure 10-3 – Stacked Turbidity Barrier or Silt Fence (c)

10.1 Sustainable soil erosion and sediment control LID Practices

Uncontrolled erosion and sediment from land development activities can result in costly damage to aquatic areas and to both private and public lands. Excessive sediment blocks stormwater conveyance systems, plugs culverts, fills navigable channels, impairs fish spawning, clogs the gills of fish and invertebrates, and suppresses aquatic life.

The application of LID concepts and the associated emphasis on minimizing the areas disturbed, as well as breaking up drainage areas into small manageable sub-catchment areas, is in total agreement with the basic principles of erosion and sediment control. The application of LID technology can easily result in improved erosion and sediment control without significant additional effort.

An effective sediment and erosion control plan is essential for controlling stormwater pollution during construction. An erosion and sediment control plan is a site-specific plan that specifies the location, installation, and maintenance of best management practices to prevent and control erosion and sediment loss at a construction site. There are five basic stages for the development and implementation of a sound erosion and sediment control plan for any land development activity:

1. Planning
2. Scheduling of Operations
3. Soil Erosion Control
4. Sediment Control
5. Maintenance

10.2 Planning

Factors that influence erosion potential include topography, soils characteristics, timing of construction, drainage ways, natural vegetation and the areal extent of land clearing activities. These are described below:

- Topography: because of the effect of runoff, the longer and steeper the slope, the greater the erosion potential. Plan the development to fit topography.
- Soil Characteristics: include erodibility, permeability, depth to water table, and soils with special hazards including shrink/swell potential or slippage tendencies.
- Timing of Construction: schedule activities during the dry season or during dry periods whenever possible to reduce the erosion potential.
- Drainage Ways: apply perimeter controls to protect disturbed areas from off-site runoff and to trap eroded material on-site to prevent sedimentation in downstream areas. Keep runoff velocities low (less than 4 to 6 feet per second) and retain runoff on-site. Stabilize disturbed areas immediately after final grade has been attained or during interim periods of inactivity resulting from construction delays;
- Natural Vegetation: any existing vegetation that can be saved will help prevent erosion. Grass buffer strips can be used to remove sediment from surface runoff. Vegetation also slows the velocity of runoff and helps maintain the infiltration capacity of a soil.

- Areal Extent of Land Clearing Activities: minimize both the extent of area exposed at one time and the duration of exposure.

10.3 Scheduling of Operations

The scheduling stage should aim to expose the smallest practical area of land for the shortest possible time. In other words, 1 acre of exposed land will yield less sediment than 2 acres of exposed land, and an area exposed for 3 months will yield less sediment than an area exposed for 6 months.

The clearing, grubbing and scalping of excessively large areas of vegetated land at one time is an unnecessary invitation to sediment problems. These initial earth disturbing activities should be kept to a bare minimum or phased appropriately. The techniques that can be used to reduce erosion include, staging of construction, temporary seeding, and /or temporary mulching.

Staging of construction involves stabilizing one part of the site before disturbing another. In this way the entire site is not disturbed at once, and the time without ground cover is minimized. Temporary seeding and mulching involves seeding or mulching areas that would otherwise lie open for long periods of time. The time of exposure is limited and therefore the erosion hazard is reduced.

10.4 Soil Erosion Control Practices

Soil erosion control practices does not begin with the perimeter sediment trap or basin. It begins at the source of the sediment, the disturbed land area, and extends down to the control structure. It is important to apply soil erosion control practices on disturbed areas to prevent off-site damage. The process of erosion occurs for the most part by the impact of falling raindrops and the energy exerted by moving water and wind. A reduction in the rate of soil erosion is achieved by controlling the vulnerability of the soil to erosion processes or the capability of moving water to detach soil particles. This can be accomplished by the use of techniques such as soil stabilization and runoff control practices.

Soil Stabilization includes vegetative, chemical, and structural measures to shield the soil from the impact of raindrops or to bind the soil in place preventing it from being detached by surface runoff or wind erosion. These include:

- Vegetative stabilization/seeding (temporary and permanent)
- Topsoiling
- Erosion control mattings
- Mulching
- Geotextiles
- Tree protection
- Preservation of mature vegetation

Runoff Control Practices are designed to reduce the amount of runoff generated on a construction site, prevent off-site runoff from entering the disturbed area, or slow the runoff moving through and exiting the disturbed area. The principal cause of soil erosion is stormwater runoff. Its control can be achieved through the proper use of vegetative and structural practices, and construction measures that control the location, volume and velocity of runoff. The following practices alone or in combination can accomplish proper stormwater handling for erosion control:

1. Reduction and Detention of the Runoff
    - Staging Operations
    - Grading and Shaping of Soil Surfaces
    - Manipulation of Slope Length and Gradient
2. Interception and Diversion of Runoff
    - Diversion Berm or Dike
    - Reverse Benches
    - Drainage Swales
    - Vegetation Buffers
3. Proper Handling and Disposal of Concentrated Flow
    - Vegetative Swales
    - Down-drain Structures
    - Outlet Stabilization

10.5 Sediment Control Practices

Whereas erosion control practices are designed to prevent soil particles from being detached, sediment control involves using practices that prevent the detached particles from leaving the disturbed area and reaching the receiving waterways. This is accomplished by reducing the capacity of surface runoff to transport sediments and by containing the sediments on site.

Sediment control practices are designed to slow the flow of water by spreading, ponding, or filtering. These will reduce the capacity of the water to transport sediment, and sediment settles out of suspension. Commonly used control practices include:

1. The preservation or installation of vegetated buffer areas downslope of the disturbed area to slow and filter the runoff
2. The construction of small depressions or dikes to catch sediment (particularly coarse-textured material) as close to its point of origin as possible
3. The construction of sediment traps or basins at the perimeter of the disturbed area to capture additional sediment from the runoff.

The amount of sediment removed from the runoff is mostly dependent upon, the speed at which the water flows through the filter, trap, or basin; the length of time the water is detained; and the size, shape, and weight of the sediment particles.

One of the underlying concepts of LID technology involves breaking up the drainage areas of a given site into very small catchment areas to disconnect hydraulically connected areas and to provide opportunities to increase the time of concentration and thus reduce peak discharges. Accordingly, this approach will benefit sediment control efforts by diffusing surface flow into many directions and providing more flexibility in the use of a variety of sediment control practices. Currently the most frequent approach is the use of Structural Practices or Sediment Basins.

Structural practices divert flows from exposed soils, store flows, retain sediment on-site, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site. Such practices may include the following:

- Silt Fences
- Stone Outlet Trap and The Riprap Outlet Trap
- Earth Dikes
- Diversions
- Swales
- Sediment Traps
- Check Dams
- Subsurface Drains
- Pipe Slope Drains
- Level Spreaders
- Storm Drain Inlet Protection
- Reinforced Soil Retaining Systems
- Gabions
- Coagulating Agents

Examples of structural practices are shown in **Figure 10-4** through **Figure 10-6**.

Figure 10-4 – Sediment Trap & Spillway

Figure 10-5 – Level Spreader

Figure 10-6 – Stone Check Dams in Swale and Stone Outlet Trap

Sediment Basins (temporary or permanent) collect and detain runoff to allow suspended solids to settle out prior to leaving the site. The following guidelines are provided:

a) For drainage basins with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, should be provided, where attainable, until final stabilization of the site. The 3,600 cubic feet of storage area per acre drained does not apply to flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around both the disturbed area and the sediment basin. For drainage basins with 10 or more disturbed acres at one time and where a temporary sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent controls is not attainable, a combination of smaller sediment basins and/or sediment traps and other BMPs shall be used. At a minimum, silt fences, or equivalent sediment controls are required for all sideslope and downslope boundaries of the construction area.
b) For drainage basins of less than 10 acres, sediment basins and/or sediment traps are recommended but not required. At a minimum, silt fences or equivalent sediment controls are required for all side slope and down slope boundaries of the construction area.
c) Areas that will be used for permanent stormwater infiltration treatment (e.g., stormwater retention ponds) shall not be used for temporary sediment basins unless effective measures are taken to assure timely removal of accumulated fine sediments, which may cause premature clogging and loss of infiltration capacity, and to avoid excessive compaction of soils by construction machinery or equipment.
d) Sizing of sediment sumps or basins – Key components in sizing sediment sumps for a BMP or in sizing a sediment basin include the soil particle size(s) to be settled, the flow velocity, and the length to depth ratio.

10.6 Inspection and Maintenance

It is important to implement a thorough inspection and maintenance program. This stage is vital to the success of an erosion and sediment control program. A site cannot be controlled effectively without thorough, periodic checks of all erosion and sediment control practices. When inspections reveal problems; modifications, repairs, cleaning, or other maintenance operations must be performed immediately. Particular attention must be paid to water handling structures such as diversions, sediment traps, grade control structures, sediment basins, and areas being revegetated. Breaches in the structures or areas being revegetated must be repaired quickly, preferably before the next rainfall.

Maintenance differs from the other activities in that it must begin as soon as the first practice is installed and must continue through all the succeeding activities until the permanent erosion control measures are established and functioning. All structural measures should be checked at the close of each workday and particularly at the end of the workweek. Also, they must be checked before and after each rainstorm of ¼ inch or more.

Diversion berms should be checked to see that they have not been breached by equipment. The condition of level spreader areas, waterways, and other outlets should also be checked. Traffic should be moving within the established access routes. Channels should be checked for sediment deposits or other impeding material. Repairs should be made promptly when damage is discovered. When repairing swales or other channels, the new lining material should be at least as erosion resistant as the original material. Vegetative measures and vegetative cover on structural BMPs require maintenance fertilizer and perhaps mowing. All sediment traps should be checked and cleaned out after each storm. Sediment basins should be cleaned out when the deposited material reaches the level designated in the plan or standards and specifications.

For further information on erosion and sediment control refer to the *State of Florida Erosion and Sediment Control Designer and Reviewer Manual (June 2007) and the Florida Stormwater, Erosion, and Sediment Control Inspector's Manual (FDEP 2005).* These manuals provide guidance for the planning, design, construction, and maintenance of erosion and sediment control practices.

11.0 CITY OF DORAL ORDINANCES

Current site development or redevelopment projects must meet, at a minimum, the stormwater quality and flood protection requirements outlined by the SFWMD, DRER, and the City of Doral. Normally, the water quality requirement is to provide retention of one inch of runoff over the entire site or 2.5 inches over the impervious areas, whichever is greater. For flood protection, at a minimum, roads and parking areas must be built at or above the 5-year, 24-hour design peak stage, the post-development runoff rate cannot exceed the pre-development rate, and the building finish floor elevations must be set at or above the 100-year, 3-day design storm event or the FEMA flood elevation, whichever is greater.

Developments incorporating LID techniques are required to adhere to the same ordinances, zoning regulations, water quality and quantity requirements, and land use designations as developments designed utilizing traditional stormwater management techniques. However, conventional zoning and land use regulations often limit the use or extent of LID alternatives available to the developer.

Typical zoning ordinances layout the requirements for the lot size and shape, the minimum width required for setbacks, right-of-way areas, and property frontages, and the width required for roadways, turnabouts, sidewalks, and driveways, and the extent of clearing and grading the site.

LID zoning alternatives provide more environmentally sensitive alternatives for development designs and encourage the use of green infrastructure. Alternative zoning options include the use of overlay districts, performance zoning, incentive zoning, impervious overlay zoning, and watershed-based zoning. These zoning alternatives provide greater flexibility for LID site development and set zoning regulations based on protecting the environmental resources of the site and often provide added incentives to the developer.

The City of Doral has amended their Land Development Code with Ordinance #2013-37, which provides general guidance for implementing green design concepts and LID practices in the Land Development Code. Article XIV, XV, and XVI, of the Doral Land Development Code, permits the use of rainwater harvesting, requires energy efficient lighting, and mandates LID practices be implemented in the development design and site plans. The City Ordinance Articles related to green design concepts and LID practices are provided in **Attachment I**.

Developers are required to implement LID practices for new developments and redevelopment sites. If it is not practical to implement LID practices on a site, the developer must demonstrate that these practices cannot be implemented because of site constraints and not because of financial impacts. Non-structural LID practices are required to be incorporated into site plans. In addition, structural LID practices must be implemented to ensure the post-development annual runoff volume does not exceed the pre-development annual runoff volume. The pre-development site is assumed to be in a natural vegetated state.

The following are the LID practices and site development criteria recommended for the City of Doral to implement for future development sites:

- Minimum vegetated/stormwater management space:
  - Commercial/Industrial – 15%
  - Residential – 25%
- Implement the following non-structural LID practices to the maximum extent practical. If not practical, developers must demonstrate that these practices cannot be implemented because of site constraints and not financial impacts.
  - Restoration and preservation of pre-development topography and soil profile
  - Preservation of native and local vegetation
  - Open space design and conservation
  - Minimization of total impervious areas
  - Reduction of DCIA
- The post-development annual runoff volume cannot exceed pre-development annual runoff volume for a defined average annual runoff event. The pre-development site condition must be assumed as natural and undeveloped when performing the pre-development hydrologic analysis.
- Implement a minimum of three (3) Structural LID practices from the following list**. At least one (1) of the chosen Structural LID practice must provide the function/benefit of treatment, aesthetics, and/or habitat as described in **Table 5-2**:
  - Bioretention Basins or Rain Gardens
  - Tree Box Filters or Infiltration Planters
  - Vegetated Swales
  - Filter Strips or Vegetated Buffers
  - Infiltration Trench
  - Exfiltration Trench or French Drains
  - Green Roofs/Rain Barrels or Cisterns
  - Permeable Pavement
  - Detention Ponds
  - Parking Stormwater Chambers

  ** Developers may introduce or propose other LID practices not included in this list for review and consideration by the City.

- Implement recommended onsite soil erosion and sediment control practices.
- Implement a five (5) year permit recertification process or add language in the permit conditions that the City has the authority to request maintenance records of LID practice every five (5) years.

12.0 CONCLUSION & RECOMMENDATIONS

The rapid land development and urbanization taking place in the City of Doral will have an impact on the natural urban hydrologic processes of surface water runoff patterns, infiltration, percolation to ground water, and evapotranspiration. Low Impact Development takes an innovative approach to mitigating these impacts and seeks to retain runoff and treat stormwater pollution at the source. The purpose of the LID Master Plan is to provide the City of Doral with guidelines and recommendations to adopt integrated LID BMPs and green infrastructure practices in future development sites.

The City of Doral has two ordinances (Ord. No. 2013-37, § 2, 12-3-2014) for the incorporation of LID practices into building plans, project designs, and site plans. The ordinances mandate that LID practices be included as part of site development plan, and provide provisions for rainfall harvesting facilities. It is recommended that the current Site Planning Regulations be amended with the addition of a requirement for a hydrological assessment of the pre- versus post-development conditions, implementation of a Site LID Design Strategies Checklist document into the current permit application, and the addition of more substantial details for the implementation of LID requirements, as well as provisions for sites where LID techniques are technically infeasible.

In addition, it is recommended that provisions for long-term maintenance, monitoring, and enforcement be developed. Long-term maintenance and inspection plans are required for LID systems and the entity responsible for the maintenance and monitoring should be clearly defined. Site Planning Regulations should be evaluated to minimize the requirements for property setbacks, traffic distribution network widths, sidewalk widths, and right-of-way areas.

Based on the data previously collected and evaluated, non-structural and structural LID planning practices were identified that will naturally treat and retain stormwater for new developments and redevelopment sites. The site planning process should incorporate LID strategies in each step of the process. The recommended priority for managing and capturing stormwater runoff is infiltration, evapotranspiration, capture and use, and treatment through biofiltration/bioretention systems.

Based on a review of the current City of Doral LID ordinance and LID management practices, the City’s current site development approach does not require any LID BMP implementation or provide any guidelines. In the City of Doral, there is no requirements for minimum vegetated/stormwater management space for commercial or residential land use development, the water quality retention requirement is the first 1 inch of runoff, and the stormwater management system is required to meet pre- versus post-development peak discharge flow only.

12.1 Soil Erosion and Sediment Control

The measures outlined effectively isolate the development site from surrounding properties and, in particular, control sediment where it is produced, thus preventing its transport from the site. Diversions, berms, sediment traps, vegetative filters, and sediment basins are examples of practices to control sediment. Vegetative and structural sediment control measures are either temporary or permanent, depending on whether they will remain in use after development is complete. Generally, sediment is retained by (a) filtering runoff as it flows through an area and (b) impounding the sediment-laden runoff for a period so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

The City of Doral implements standard on-site practices for sediment control which include inlet protection systems, silt fence, turbidity barriers, and temporary gravel construction entrances and exits. However, it is recommended that the City should include other erosion control practices as described, such as soil stabilization and runoff control. The erosion control practices would ensure the control of sediment at the source and again at the control structure, not only at the control structure as it is currently established.

13.0 SELECTED REFERENCES

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