Town of Cutler Bay
Stormwater Manual

December 2018

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Table of Contents

Executive Summary

The Town of Cutler Bay is actively engaged in stormwater management, stormwater master planning, compliance with State and Federal requirements, and protection of its natural areas and receiving waters. Looking ahead to future development and re-development, the Town is working to manage its stormwater infrastructure, minimize flooding, and maintain or improve water quality. An important component to this goal is a commitment to Low Impact Development (LID) techniques and Green Infrastructure (GI) practices.

LID and GI rely on minimizing impervious surface and promoting infiltration, evapotranspiration, and water reuse to manage stormwater on developed land. The reduction in storm water and pollutants using LID practices can reduce the required peak discharges and volumes that must be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and Best Management Practices (BMPs). In some cases, the use of LID practices may eliminate the need for structural controls entirely. Hence, LID practices can be viewed as both a water quantity and water quality management tool. The following LID techniques are explained in this document: Protecting existing vegetation, enhancing highly urban soils, selecting and utilizing native vegetation, minimizing impervious cover, preserving natural features, water conservation and reuse, and meeting multiple regulations through stormwater management.

Guidance and specifications for Best Management Practices (BMPs) are provided in this Manual and include the description, variations, key advantages, key limitations, and performance standards for the specific practices. This Manual also describes additional state and county process and resources as guidance for developers. The following BMPs are provided in this document: shallow bioretention, rain gardens, water quality swale, pervious pavement systems, exfiltration trenches, rainwater harvesting, and green roofs.

Developers are encouraged to review this Manual and referenced resources prior to initiating site design and to contact the Public Works Department early in the design process to schedule a Pre-Concept Meeting. This Manual and the Town's Post-Construction Stormwater Ordinance are intended to engage the development community and promote Cutler Bay's stormwater goals through the design and implementation of LID and GI.

This Manual provides examples of simple changes in design, like utilizing a traditional landscape island as bioretention, to help meet both water quality goals and landscape requirements.

1 Introduction and Approach

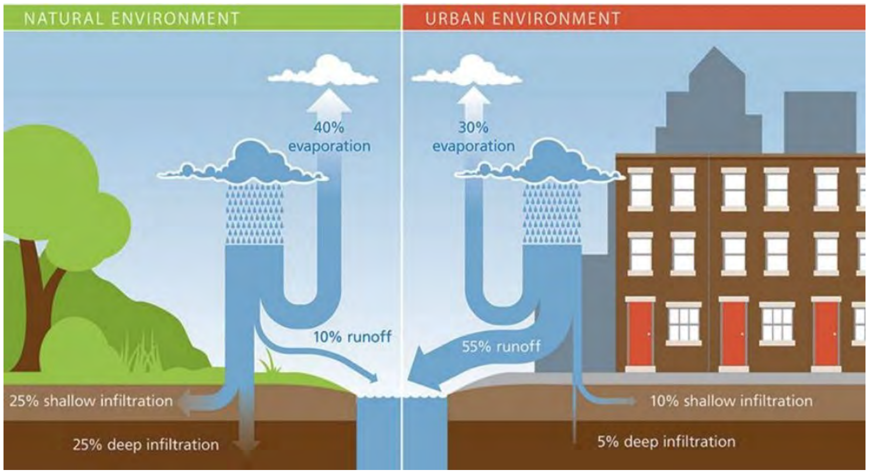
1.1 WHY STORMWATER MANAGEMENT

This Manual is intended to: assist developers in understanding the regulatory processes involved in the design of stormwater management systems in Cutler Bay; provide guidance for the successful design, implementation, and maintenance of these systems; and encourage the use of Low Impact Development (LID) and Green Infrastructure (GI).

Stormwater is created when rain that falls to the ground does not infiltrate into the soil. The volume of stormwater runoff varies based on a number of factors; including: the amount of rain that falls and how quickly or intensely it falls, the moisture condition of the soil prior to rainfall, and the land cover in the area where the rain falls. Subsurface conditions, such as the elevation of the groundwater table or soil permeability, can also play a role in the volume of storm water that is generated for any given rainfall event. Developed lands produce storm water more quickly and in larger volumes than most natural landscapes due to high amounts of impervious surfaces.

Natural landscapes in Florida are highly capable of managing rainfall for most storms without generating a significant amount of stormwater. Leaves intercept and evaporate rainfall, plant roots draw up water for photosynthesis, wetlands provide natural detention and purification, and un-compacted soil allows rainfall infiltration. The rainfall that soaks into the soil is taken up by plants, moves laterally to provide base flow for nearby waterbodies, or moves through the soil and replenishes the groundwater.

As land is developed, natural areas are replaced by shopping areas, centers of business and industry, schools, and residential areas. Storage volumes in natural depressions and even wetlands are often reduced. Impervious surfaces replace trees and plants that previous captured some of the rainfall. Natural soils that once infiltrated rainfall is scraped and removed, and the remaining soil is compacted. Rainfall that once evaporated and seeped into the soil now runs across the ground much more readily, increasing the amount of stormwater that is delivered to local waterways. As stormwater discharges from rooftops and travels over driveways, parking lots, yards, and roads, it picks up sediment and other pollutants such as litter, pathogens from animal waste, pesticides and herbicides used on lawns and landscapes, oils and greases from cars and industries, dusts, and other substances. These pollutants are carried in the stormwater runoff to receiving waters.



The high levels of impervious surface found in the urban environment have both increased the volume of stormwater into the overall system and increased the pollutant load into local waterways.

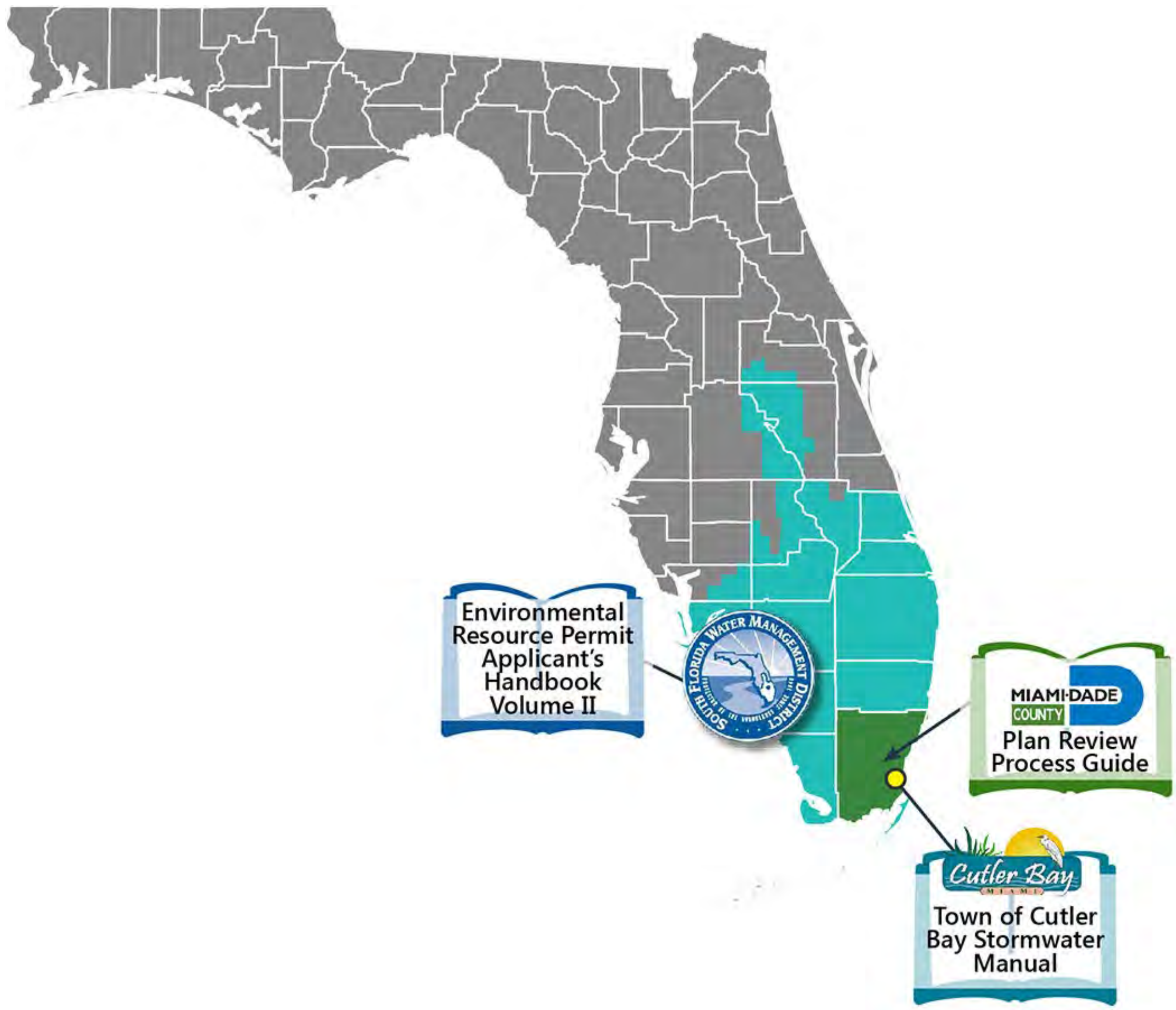
When properly protected and managed, soil and vegetation can provide substantial storm water volume reduction even on urban developments. The role that soil and vegetation can play in stormwater management for urban and suburban landscapes must therefore not be underestimated. The Town of Cutler Bay promotes the use of Low Impact Development (LID) to manage stormwater. LID techniques and Green Infrastructure rely on the mechanisms of infiltration and evapotranspiration to manage storm water on a land development. Many of the stormwater controls included in this Manual use soil and vegetation to improve storm water quality and, to a lesser degree, control stormwater quantity.

1.2 REGULATORY FRAMEWORK AND PURPOSE

Recognition that stormwater is a major source of pollution prompted the United States Environmental Protection Agency (EPA) to initiate the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit program for local governments, under authorization by the United States Clean Water Act (33 U.S.C. §1251 et seq. (1972)). NPDES-MS4 permitting in Florida has two phases. Phase I addresses discharges of stormwater runoff from "medium" and "large" MS4s (i.e., those MS4s located in incorporated areas with populations of 100,000 or greater). Phase II of the program includes additional MS4s that are urbanized but meet lower population thresholds. Cutler Bay, along with more than thirty other communities in the Biscayne Bay watershed, was permitted by the Florida Department of Environmental Protection (FDEP) under Phase I as co-permittees under Miami-Dade County’s MS4 NPDES permit. The co-permittees are regulated under one NPDES permit, but each co-permittee is required to develop and employ their own stormwater management program. On October 1, 2017, the Town of Cutler Bay entered into a five-year agreement for shared stormwater management between Cutler Bay and the County. The County provides maintenance of the municipal stormwater system and is reimbursed on an agreed-upon basis by Cutler Bay.

In ‘An Overview of Stormwater Management Practices’ in Miami-Dade County (Chin, 2004) the local jurisdictions and corresponding stormwater regulations currently applicable to Cutler Bay are outlined. These regulations, as they pertain to this Manual, are summarized in the following sections. The regulatory agencies and available reference materials are illustrated in **Figure .1**.

Figure 1.1. Map of regulatory agencies and associated guidance documents



SFWMD

Florida is divided into five water management districts. The South Florida Water Management District (SFWMD) issues environmental resource permits for the construction and operation of surface-water management systems in Miami-Dade County, including within Cutler Bay. SFWMD's development requirements are outlined in SFWMD's Environmental Resource Permit Applicant's Handbook Volume II.

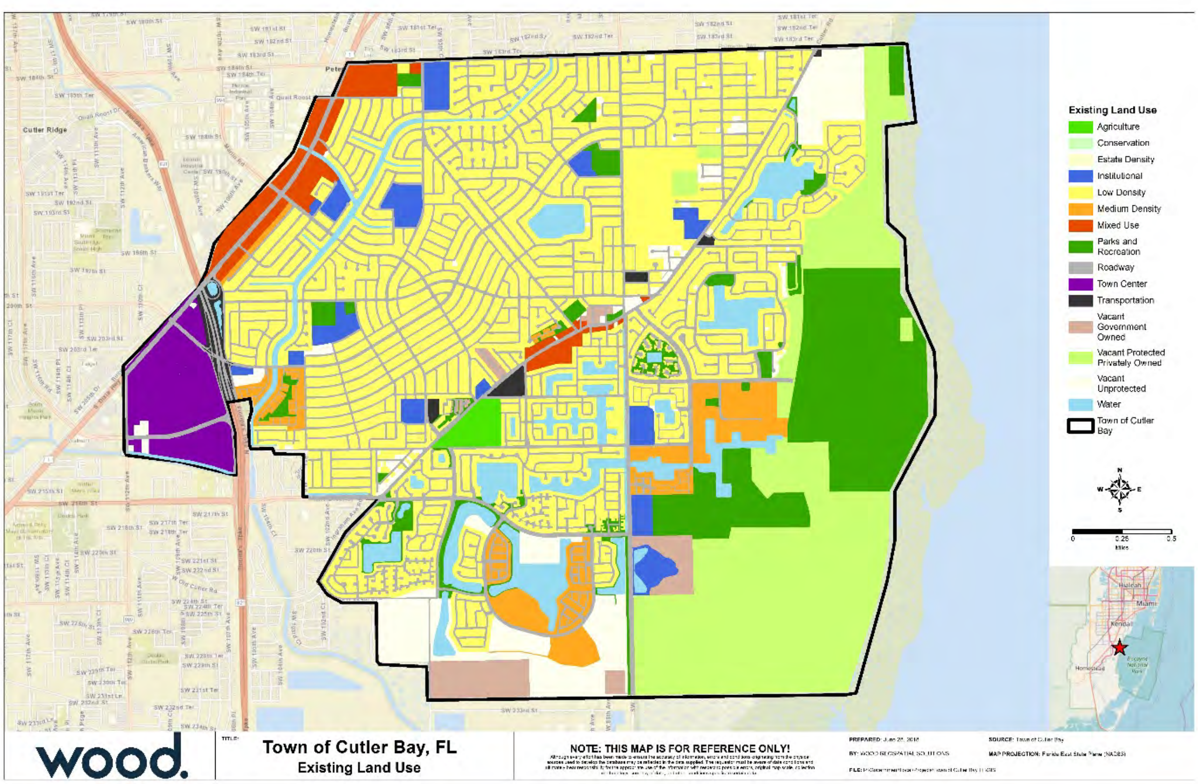
DERM

The SFWMD has delegated authority to the Miami-Dade Department of Environmental Resources Management (DERM), which conducts development plan review per Chapter 24 of the Code of Miami-Dade County Code of Ordinance. A Class II permit is required to install and/or alter any outfall or overflow system in, on, under or upon any waterbody.

Cutler Bay

The Town of Cutler Bay is located in Miami-Dade County and has a total area of approximately ten square miles. It is bordered by Biscayne Bay to the east; and the communities of Palmetto Bay to the north; and Goulds and South Miami Bay to the south and west. The population is approximately 45,000. A map of the Town of Cutler Bay's existing land use, from the Town's Stormwater Master Plan, is shown below in **Figure 1.2**.

Figure 1.2. Existing Land Use in Cutler Bay



Most of the Town is developed land and the bordering communities also consist primarily of developed land. Potential future development in Cutler Bay will therefore be predominately redevelopment projects. Undeveloped areas currently consist of: privately-owned conservation land in the eastern and southern portions of the Town, government owned parcels in the south, sections of land along Old Cutler Road, and other parcels scattered throughout the Town. In the coming years, Cutler Bay anticipates development and redevelopment projects that may increase impervious surface, increase urbanization, and reduce the area of undeveloped land. To reflect the needs of Cutler Bay, this Manual promotes the application of LID principles to mitigate the impacts of these changes on drainage and water quality.

The Town includes assessment of stormwater drainage facilities as part of concurrency review for potential new developments under Article XV.Sec.3-240. Projects are reviewed to ensure the Town can provide adequate stormwater infrastructure for the development. Under Section 18-26, Cutler Bay prohibits disposal of stormwater by allowing or causing the same flow on, over or across any adjoining property, right-of-way, easement, or public or private drainage canal.

Similar to other communities in Florida, Cutler Bay has large areas of impervious surface which subsequently generate large volumes of sediment-laden stormwater. LID and GI can be part of the solution to water quanity and quality.

To be able to continue to provide stormwater management and plan for future development, the Town is committed to encouraging the use of green infrastructure and LID techniques. Cutler Bay completed thorough stormwater modeling as part of their Stormwater Master Plan with a goal of evaluating potential changes in land use due to redevelopment and the development of vacant parcels. Calculations were prepared with the intention to keep post-development discharges at or below pre-development rates.

Cutler Bay anticipates that, at projected rates of land use and development, up to 50% of the Town's land area will potentially be impervious surface. By implementing this Manual and a Town plan review process that incorporates LID principles, Cutler Bay expects to meet its goal of maintaining peak flow levels for the three watersheds (C-100, C-1 and DA-4). Additionally, the Town recognizes that effective LID stormwater management practices are essential to encourage and support quality development and redevelopment, which is critical to the local community and economy. <u>The Town's NPDES MS4 permit requires jurisdictions to revisit their land development codes to ensure they promote low impact development to effectively support water quality improvement goals.</u>

In Florida, many communities are developing LID guidance for developers, evaluating the performance of BMPs under local conditions, and providing updated specifications for improved BMP performance. These Manuals select appropriate BMPs for local conditions while meeting state and federal requirements. Lists of several Florida municipalities with LID Manuals as well as several Florida LID projects are provided in Appendix A.

Through Cutler Bay's Stormwater Program, the Town is committed to help enhance and protect water quality through the use of low impact development and green infrastructure practices.

In addition, developers are encouraged to pursue the Green Building Program Designation according to **Chapter 3, Article 74** of the Town's Code of Ordinances. This designation allows buildings that meet the prerequisites to obtain available incentives; such as: increased floor area, increased height, reduction in parking, expedited plan review, and eligibility for a green building award.

1.3 CHALLENGES AND SOLUTIONS OF INFILL/REDEVELOPMENT DESIGN

Stormwater management on an infill/redevelopment can be more difficult than a standard development site due to limited space, access to surrounding infrastructure, compacted soils, and other limitations. For example, a stormwater pond takes up valuable space on a development site. When dealing with a more confined land area, a comprehensive set of LID practices and several BMPs may need to be used in series. Several swales, located between several parking areas with pervious pavement, may better suit the site than a stormwater pond. LID/BMPs most likely to be applicable to parcels in Cutler Bay are included in this Manual. Provided in **Table 1.1** below, is a summary of challenges and potential solutions for highly impervious redevelopment sites.

Table 1.1. Challenges and potential solutions for highly impervious redevelopment sites

Challenge	*Solution*
✓ **GI can compete for space with a variety of existing utilities and infrastructure.**	✓ Be creative with the site layout by incorporating GI within site landscape and parking. Utility-specific horizontal and vertical setbacks should be met. ✓ When encroachment is unavoidable, additional protection or encasement of the utility or protection of the infrastructure may be warranted. Construction sequencing should be planned to minimize disruption of utility service.
Challenge	***Solution***
✓ **Urban soils are often highly compacted and nutrient-deficient, and limit the growth of plants and infiltration of stormwater.**	✓ Many GI Practices are required to include a specified soil mix and integrate an underdrain system. Soil amendments can also be added to the in situ soils if deemed necessary. ✓ Soil can be tilled or excavated if more favorable conditions are identified deeper within the soil profile.
Challenge	***Solution***
✓ **Concentrated runoff and potentially high sediment loads can be expected in ultra-urban environments.**	✓ It is important for the design to incorporate energy dissipation and pre-treatment practices that will capture/collect sediment to prevent clogging. ✓ Highly tolerant and hardy plants should be selected. ✓ Routine maintenance must be specified and provided.
Challenge	***Solution***
✓ **Highly polluted runoff from urban sites may infiltrate into subsoils.**	✓ Specify a lined stormwater planter, bioretention, green roofs, and/or rainwater harvesting, which rely on evapotranspiration and reuse rather than infiltration. ✓ Segregate the most polluted runoff and treat with special practices—both structural and nonstructural (for example, special drains and spill cleanup practices). ✓ Implement pollutant source control practices to limit the exposure of potential pollutants to rainfall.
Challenge	***Solution***
✓ **Small commercial sites will be limited in space to meet multiple zoning, landscape, parking, and stormwater requirements.**	✓ Bioretention areas in parking lots can typically deliver required stormwater management and use plants that meet the 10% tree planting and landscaping requirement in accordance with the **City's Landscaping and Tree Preservation Ordinance (Sec. 3-102).** ✓ Permeable pavement can function both as a parking area and a stormwater management facility, offering a space-saving solution on expensive real estate.

Challenge	***Solution***
✓ **Urban GI is often subject to higher public visibility, greater trash loads, pedestrian use, vandalism, and vehicular loads.**	✓ To address public visibility, a routine maintenance plan is required to keep GI Practices free of trash and debris. ✓ Signage is also recommended for GI Practices to educate and increase public awareness. ✓ Low-stature plants and a more formalized planting plan can be used to blend practices into surrounding landscapes. ✓ Low fences, grates, or other measures can be installed to prevent damage from traffic and pedestrians.
Challenge	***Solution***
✓ **GI stormwater practices are perceived to be more expensive than traditional stormwater practices.**	✓ GI Practices can cost less to install and maintain than traditional stormwater practices. For example, cisterns can reduce the need for irrigation and even potable water. Native drought-tolerant plants can also eliminate the use of potable water and fertilizers. Often, less storm pipe, curb, and gutter are needed in design.
Challenge	***Solution***
✓ **Changing regulations require creative methods to reduce the volume of runoff leaving the site.**	✓ This Manual was created to help simplify and streamline the design process and take the uncertainty out of the design.

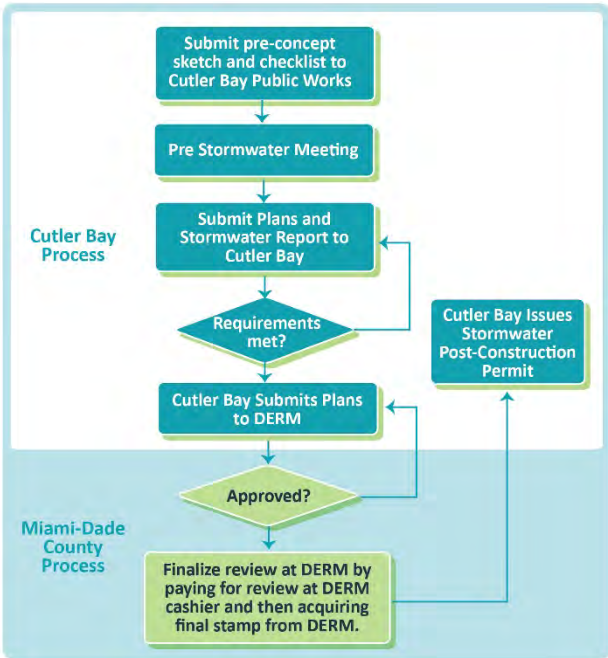
2 Stormwater Plan Submittal Process

2.1 GENERAL REQUIREMENTS AND APPLICABILITY

In addition to meeting county, state, and federal requirements, stormwater treatment systems shall be designed to combine structural and non-structural BMPs in series to achieve the water quality and quantity goals. **Per Cutler Bay's Post-Construction Stormwater Ordinance, the Town of Cutler Bay has authority to review stormwater management and issue a Stormwater Post-Construction Permit for all development and redevelopment 1 acre or more or adding an increase in impervious area of 10,000 sq. ft. or more. The runoff discharge rates shall be limited to pre-development conditions based on the 25-year design storm event. (Developments that consist only of a single family residential lot are excluded from this requirement.)** This shall be met by utilizing the stormwater design process outlined in **Section 3** of this Manual.

Stormwater review is completed by both Cutler Bay and Miami-Dade County according to the process shown in **Figure 2.1**.

Figure 2.1. Plan Review Process



2.2 REQUIRED SUBMITTAL INFORMATION

The post-construction stormwater plan is the engineering plan that describes the site designer's approach for achieving the stormwater performance standards on a proposed land development. In general, the plan describes how the hydrologic characteristics of the site will change as a result of the proposed land development, how the appropriate performance standards for stormwater will be achieved, and presents the detailed designs for any BMPs that will be permanently located on-site. Once approved by the Town, the project will be forwarded to DERM for their approval.

A Storm Water Post-Construction Permit cannot be obtained without approval of the post-construction storm water plan by the Town. This section defines the development and redevelopment process in three steps:

1. Pre Stormwater Meeting
2. Stormwater Report
3. Operation and Maintenance Agreement

Pre-Stormwater Meeting

The Town of Cutler Bay requires the submittal of a pre-concept sketch and attendance at a pre-stormwater meeting. This process does not require design calculations or analyses, nor does it result in a plan approval. Rather, the process is used to characterize the hydrologic aspects of the property in its existing condition with the objective of optimizing the future on-site storm water system design and plan review process. Project approval will not be considered without proof that the pre-stormwater meeting has occurred for the proposed development.

The pre-concept sketch is assessed at the pre-stormwater meeting to determine the opportunities and limitations of the site in terms of the allowable flow rate, incorporation of LID elements, and use of BMPs. The process occurs early in the site planning process and aims to identify the site hydrology, minimize impervious surface, maximize the use of LID practices, and minimize the need for constructed drainage features. The main benefits of the pre-stormwater meeting are:

- Discussions occur with Town staff who are very familiar with the Town's watersheds and the pre-development flow rates of undeveloped parcels
- Meet goals of the Town's Stormwater Master Plan
- Early identification of opportunities or limitations for LID and BMPs
- Optimization of the existing stormwater infrastructure and natural hydrologic features
- Potential reduction in grading, construction and maintenance costs through early planning of stormwater LID practices
- Understanding of potential development incentives and overlap within existing Town code
- Early interaction with Town staff makes for more efficient development plan reviews, potentially reducing plan approval times

The applicant shall prepare a pre-concept sketch in accordance with the checklist provided in Appendix B of this Manual. The checklist provides a complete inventory of the desired contents of the sketch. As many of the checklist elements as possible should be provided, based on the availability of data. Those elements that are not applicable to the project or not available must be indicated as such on the checklist. Proper use of the checklist will facilitate a more meaningful and efficient pre-stormwater meeting.

It is recognized that some checklist elements will be easy to gather by visual inspection or using maps available to the general public (e.g., USGS Quadrangles, NRCS soil surveys, publicly available aerial photography, etc.), while the provision of other requested elements may require engineering field tests or environmental surveys. While the Town welcomes and encourages the collection of all the elements on the checklist in order to develop a well-informed storm water management vision for the site, engineering or environmental tests or surveys are not required by the Town for inclusion with a pre-concept sketch. Checklist elements that would require such tests or surveys can be marked as "No Data" if the tests have not been previously performed.

Note that engineering or environmental tests, surveys, and related analyses may be required later in the land development process to obtain a Stormwater Post-Construction Permit or other local permits.

Stormwater Report

The applicant shall prepare the stormwater report in accordance with the applicable checklist provided in Appendix B of this Manual. The submittal shall, at a minimum, include all of the elements listed in the checklist with the exception of those elements that are not applicable to the project, which must be indicated on the checklist as “not applicable.” A fully completed checklist must be included with the submittal at the time it is submitted for review. Proper use of the checklists will ensure submittal of complete plans and will facilitate efficient plan review processes.

Operation and Maintenance Agreement and Annual Inspections

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. Specific information about the operation and maintenance of BMPs are included in Section 4 of this Manual. A legally binding Inspection, Protection, and Maintenance agreement is required for all approved BMPs. To ensure ongoing maintenance of all private facilities shall provide a certificate of inspection from a registered engineer each year. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see Appendix B of this Manual.

The Town of Cutler Bay shall conduct regular inspection of public and private facilities for compliance. Priority inspections shall be conducted on properties that do not submit the annual inspection records. The property owner (which may be the developer, a business, private individuals or a homeowners' association) shall provide inspection records and comply with maintenance findings from all inspections. Failure to comply will result in maintenance being conducted by the Town with the incurred time and materials cost charged to the property owner.

DERM Review Process

Once a project is issued a Stormwater Post-Construction Permit from Cutler Bay, plans are forwarded to DERM for their plan review. DERM's Environmental Review Permit (ERP) process includes stormwater quality and quantity controls, according to Chapter 24 of the Miami-Dade County Code of Ordinances. Plans will not be forwarded to DERM without approval from Cutler Bay. If plans are altered as a result of DERM plan review and these changes alter site drainage or BMPs, the plans must be re-submitted to Cutler Bay and re-approved.

3 Stormwater Design Process

3.1 INTEGRATED STORMWATER MANAGEMENT/LOW IMPACT DESIGN

Interest in and awareness of the need to better manage stormwater in urban areas has increased in recent years. Traditional stormwater management techniques have historically resulted in large amounts of impervious surfaces (e.g., roads, sidewalks and rooftops). Conventional development approaches to stormwater management often use practices to quickly and efficiently convey water away from developed areas. This results in large volumes of storm water, and therefore pollutants, flowing directly to receiving streams and other waters.

From a stormwater perspective, Low Impact Development (LID) is an approach to land development and redevelopment that works with nature to manage storm water as close to its sources as possible. LID employs principals such as preserving and re-creating natural landscape features and minimizing impervious surfaces to create functional and appealing site drainage systems that treat stormwater as a resource rather than a waste product. For purposes of this Manual, LID is considered a non-structural (i.e., natural, not constructed) approach to stormwater management.

The reduction in storm water and pollutants using LID practices can reduce the required peak discharges and volumes that must be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and BMPs. In some cases, the use of LID practices may eliminate the need for structural controls entirely. Hence, LID practices can be viewed as both a water quantity and water quality management tool. The wide variety of benefits that can may result from the use of LID/BMPs in Cutler Bay are listed below.

Town of Cutler Bay Benefits

- Effective tool for stormwater management
- Balances sustainability and economic growth needs with environmental protection
- Aligns with Cutler Bay's Stormwater Management Plan
- Reduces the Town's infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm drainage system)
- Decreases flooding risks for small storms
- Creates attractive and multifunctional public spaces
- Encourages private sector participation in sustainable storm water infrastructure at residential, commercial and industrial properties
- Supports stormwater pollution reduction requirements of the NPDES-MS4 permit

Land Developer Benefits

- Reduces land clearing and grading costs
- May reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- May reduce construction, materials, and maintenance costs
- Reduces storm water management costs
- Increases lot and community marketability
- Provides easier compliance with wetland and other resource protection regulations
- Creates the possibility to obtain Leadership in Energy & Environmental Design (LEED) points
- In line with **Chapter 3, Article 74** of the Town's Code of Ordinances, allowing further development incentives

Property Owner Benefits

- May reduce maintenance costs
- Can increase a property's landscape/hardscape aesthetics
- Can provide functional green spaces for recreation and enjoyment of the natural environment
- Creates more pedestrian friendly neighborhoods
- Increases property marketability

Environmental Benefits

- Preserves integrity of ecological and biological systems
- Protects site and regional water quality by reducing sediment, nutrients, and pollutant loads to local waterways
- Reduces impacts to terrestrial and aquatic plants and animals
- Preserves trees and natural vegetation
- Mitigates the heat island effect and reduces energy use

In completing the required checklist (refer to Appendix B), developers are required to evaluate the use of LID, including the following techniques:

Protecting Existing Vegetation

Protection of natural vegetation is integral to the success of a LID site design. Existing vegetation is more established and more likely to be suited to the site than newly planted vegetation. Established vegetation has a larger and stronger root system, increasing water update by the plant while also improving soil infiltration. Natural vegetation is likely to be larger, promoting evapotranspiration and providing shade. Vegetation, especially trees, that can be preserved on a site can fulfill some landscaping requirements while providing landscaping cost savings and improving land value.

Enhancing Highly Urbanized Soils

Excavation, grading, filling and topsoil removal can result in compaction that reduces soil permeability and result in soils that are low in nutrients and organic matter necessary for optimal plant growth. These highly urban soils present challenges for the management of stormwater and often soil restoration can help mitigate these challenges.

Soil restoration refers to the process of tilling and adding compost and other amendments to soils to restore them to their predevelopment conditions, which improves their ability to reduce post-construction storm water runoff rates, volumes, and pollutant loads. The soil restoration process can be used to improve the hydrologic conditions of pervious areas that have been disturbed by clearing, grading, and other land disturbing activities.

Organic compost and other amendments can be tilled into soils in these areas to help create healthier, un-compacted soil matrices that have enough organic matter to support a diverse community of native trees, shrubs, and other herbaceous plants.

Soil restoration can also be used to increase the stormwater management benefits provided by other BMPs on sites that have soils with low permeability (i.e., hydrologic soil group C or D soils). The soil restoration process can be used to help increase soil porosity and improve soil infiltration rates on these sites, which improves the ability of these and other low impact development practices to reduce post-construction storm water runoff rates, volumes, and pollutant loads.

Selecting Native Vegetation

Native plants are adapted to the local climate and therefore are more likely to thrive on a developed site. Native plants also tend to have a deeper and more developed root system, which will increase survival in well-drained media and reduce the need for irrigation. Per Section 3-72, Cutler Bay requires all developments to comply with the state friendly landscaping guiding principles of the Florida Yards and Neighborhoods Program. More information is available at http://ifas.ufl.edu.

A listing of native and approved non-native trees and approved shrubs and ground covers is available in the County Comprehensive Development Master Plan Conservation, Aquifer Recharge and Drainage Element and in the County Landscape Code and Manual. The Florida Department of Agriculture and Consumer Services also maintains a list titled “Urban Trees for Florida”. Invasive and undesirable species can be harmful to the natural environment. The County also maintains a list of prohibited trees and plant material under Policy CON-8I.

Minimize Impervious Cover

Following the maximization of preserved natural areas and vegetation, LID practices should target the reduction of the overall imperviousness of the development site. These techniques directly minimize the stormwater that will be generated from the development. Such practices include roadway width minimization and reducing parking and building footprints.

Use Preserved Natural Features

A site designer may be able to identify and preserve other natural features and hydrologic resources on a site for the purposes of reducing stormwater volume, pollutants, and peak flow, providing stormwater storage, reducing flooding, preventing soil erosion, and promoting infiltration and evapotranspiration. It should be noted that projects that impact floodplains, natural water bodies, wetlands, or waters of the state require review and additional requirements from SFWMD through the ERP review process. Some of the natural features that should be taken into account are listed below:

- Areas of undisturbed vegetation
- Floodplains and riparian areas
- Ridgetops and steep slopes
- Natural drainage pathways
- Intermittent and perennial streams
- Wetlands
- Aquifers & recharge areas
- Soils
- Shallow bedrock
- High water table
- Other natural features or critical areas

Water Conservation and Reuse

Rainwater that falls on development site can be collected and conveyed into an above- or below-ground storage tank or directed to areas for update by vegetation or infiltration. This technique results in less stormwater runoff and provides water conservation concurrently. There are opportunities for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g., car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), supply for chilled water-cooling towers, replenishing and operation of laundry, if approved by the Town.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system. Rain tanks and cisterns are used to intercept, divert, store, and release rain falling on rooftops for future use. Roof downspouts can be directed to vegetated areas, bioretention, cisterns, or planter boxes, and routing runoff into vegetated swales instead of gutters.

Meeting Multiple Regulations

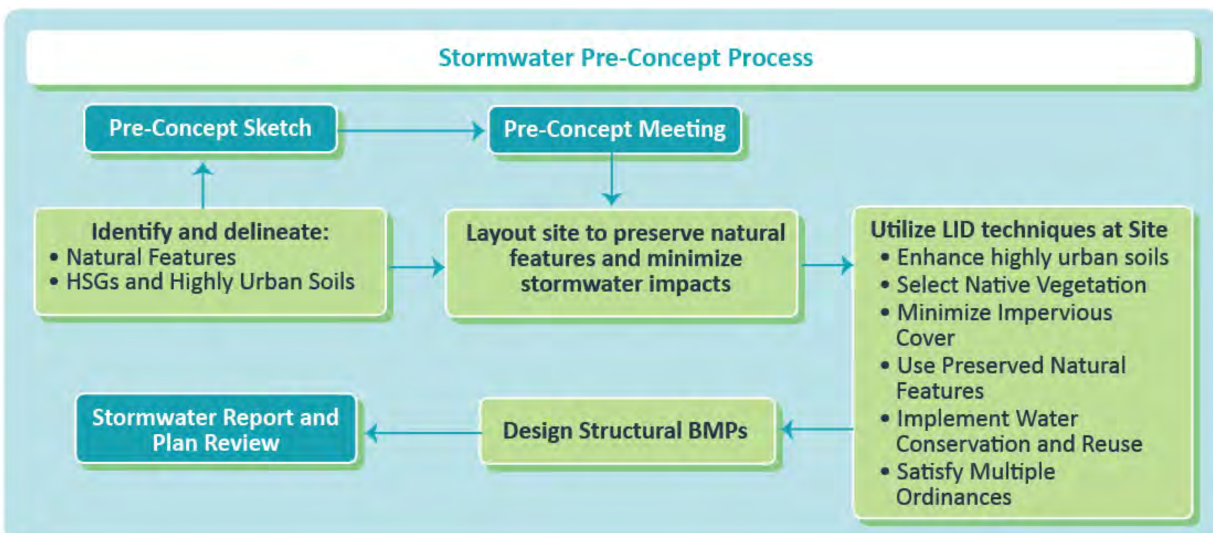
Requirements for number of trees and square feet of landscaping required for developments in Cutler Bay are defined in Chapter 3, Article VII of the Cutler Bay Code of Ordinances. Additional requirements for site canopy coverage, buffer areas, and tree preservation are also included. By utilizing vegetated BMPs, a developer may be able to also meet landscaping requirements or reduce the additional cost and space required for landscaping.

Cutler Bay encourages the preservation of existing trees and will allow protected trees to count toward landscape requirements. Tree barrier protection, when placed at least 10 feet from tree trunks, is required to protect existing trees on a development site. This protection practice also prevents soil compaction.

3.2 SITE DESIGN STEPS

Developers shall use an LID approach for site stormwater management. Projects must complete a comprehensive, multi-step process, as illustrated in **Figure 3.1**. Additional information about the required LID techniques, Pre-concept Meeting, Stormwater Report, and plan review are provided above in **Sections 2.2 and 3.1.**

Figure 3.1. Project Evaluation Flow Chart



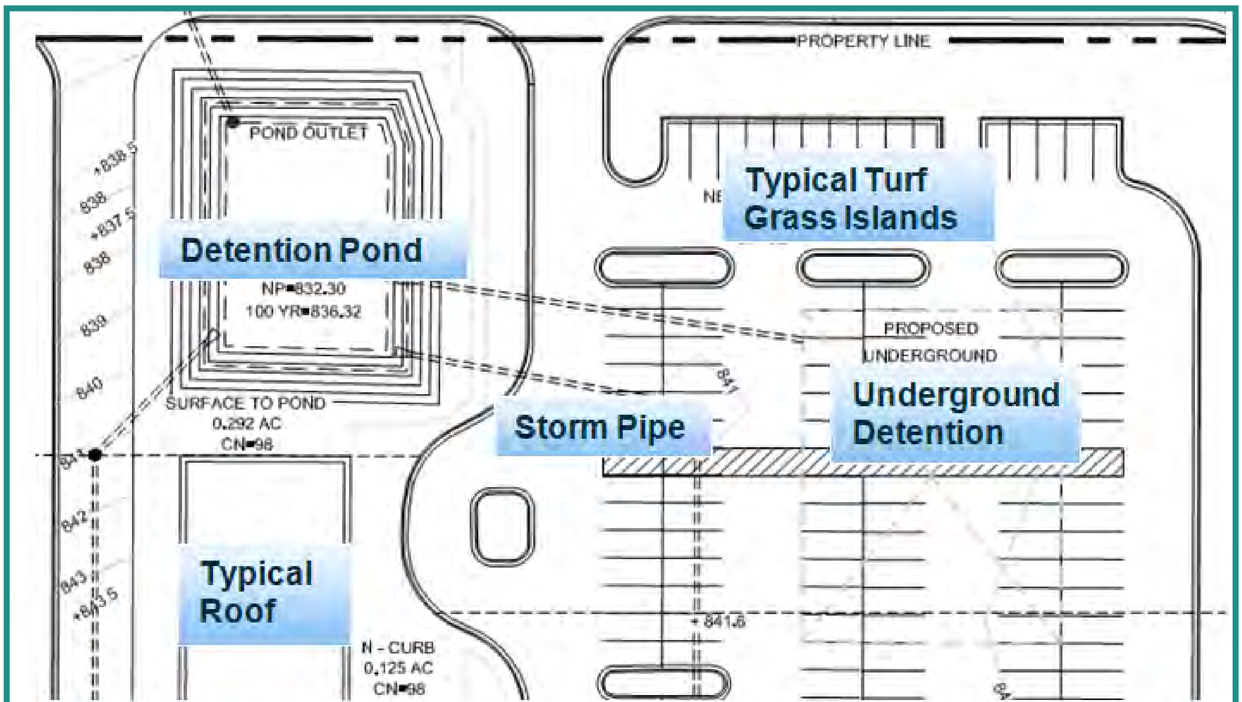
3.3 SIZING CRITERIA

"Presumptive criteria," has been codified in the statewide Environmental Resource Permitting (ERP) rule, Chapter 62-330, F.A.C. BMPs shall be utilized for the retention or detention of stormwater runoff. The stormwater treatment target is removal of 80 percent of the annual average load of post development pollutants for Class III waters, and 95 percent removal for Outstanding Florida Waters. These minimum targets are codified in Chapter 62-40.432(2)(a), Florida Administrative Code. Further, Section 373.4131(3)(b), F.S., authorizes the presumptive BMP based approach.

The Environmental Resource Permit Applicant's Handbook Volume II shall be followed to meet stormwater quantity and quality sizing criteria. The handbook defines the stormwater quality standard by the performance of the stormwater system assuming it is designed and operated according to the handbook. This method of “presumptive criteria” assumes that this design and operation will allow the project to meet State water quality standards.

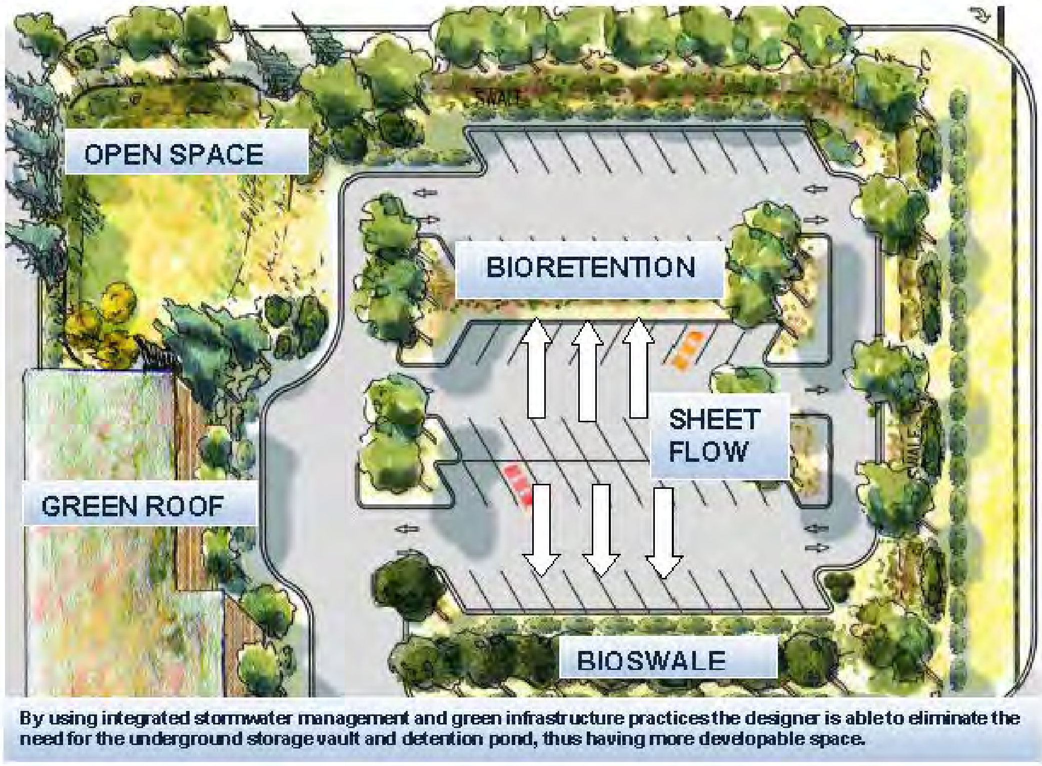
3.4 EXAMPLE PROJECT

Below is an example project that demonstrates a traditional site layout and one that utilizes LID and GI. The traditional site layout consists of a high amount of impervious surface, typical landscape islands with turf grass, and a large detention pond to manage the runoff generated from the impervious surface. In contrast, landscape islands shown in the LID and GI site layout function as bioretention areas, the perimeter landscape provides stormwater management through the use of bioswales, and the rooftop utilizes a green roof to further manage the runoff. Through the use of small on-site distributed systems, the LID and GI site layout is able to eliminate the need of a detention pond.



Conventional small commercial parking lot layout utilizing traditional curb and gutter system, underground detention, detention pond, and traditional landscaping.

This site layout utilizes a traditional stormwater management approach to meet both water quality and quantity goals. All stormwater generated from the impervious surface is conveyed to a typical detention pond.



This site layout on the same property utilizes the principles of low impact development and green infrastructure practices. Stormwater from the impervious parking areas is first directed by sheet flow to bioretention landscape islands that serve a multifunctional purpose and then drain to the perimeter bioswale. Open space is protected and the impervious rooftop is turned to pervious by the use of a green roof.

4 Best Management Practices

Structural storm water best management practices (BMPs) are engineered facilities that are intended to reduce storm water pollutants and/or mitigate the effects of increased peak discharge, volume, and velocity resulting from land development. This section provides detailed descriptions and design specifications for the structural practices that are acceptable for use in Cutler Bay to address the storm water performance standards established in Section 3. In other words, the use of one or more of the structural practices described in this chapter in land development design will:

The Cutler Bay Storm Water Management Ordinance requires that all of the structural BMPs used for a land development be designed, constructed, and maintained in accordance with the specifications presented in this Manual. As referenced in Section 2.2 Operation and Maintenance Agreement and annual Inspections are required for all BMPs.

The design specifications for the BMPs in this chapter facilitates their integration into many common urban land uses and can be used on both public and private property. Practices may be constructed individually, or as part of larger construction projects. Decentralized management strategies are encouraged to be tailored to individual sites (as demonstrated in the example project in Section 3.4 Example Project); which can eliminate the need for large-scale, capital-intensive centralized stormwater control.

Specifications for each BMP deemed acceptable for use in Cutler Bay is provided in the sections that follow, arranged by practice in practice-specific design sheets. **Table 4.1** below lists these BMPs with a brief description.

The first page of each BMP design specification sheet is set up to be a concise overview of the practice and provides **the description, variations, key advantages, key limitations,** and **performance standards** for the specific practice.

In addition, each BMP is provided a rating (low, medium, or high) in the following **development attribute** categories as an initial step in evaluating the applicability of the BMP to a given site. See **Figure 4.1** and the explanation on the following page.

Figure 4.1. Stormwater Practice Attributes

- **Construction Costs**: The estimated implementation costs associated with the construction of the BMP per acre of directly connected impervious area treated.
- **Operation and Maintenance Costs**: The estimated annual costs associated with operation and maintenance activities for the BMP.
- **Ground-Level Encroachment**: Encroachment onto potential usable, open space on the ground-level surface of the site.
- **Building Footprint Encroachment**: Encroachment onto site area that could otherwise be used for building footprint.
- **Triple Bottom Line**: The ability of the BMP to provide social, environmental, and economic benefits (land value, energy efficiency, etc.).

After the first page, the remaining pages of each BMP specification sheet provides the following information:

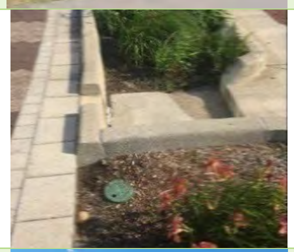
General Application: The General Application Section provides an overview of the practice, variations of the practice, and various areas in a site development that the practice can be used in (parking lot islands, courtyards, right of ways, etc.). In addition, a rendering labeled with the basic components of the practice is provided in this section.

Planning and Physical Feasibility: The Planning and Physical Feasibility Section provides information that should be determined early in the process to determine what type of specific constraints are on your site and what the specific suitability of the practice is on the development site. For each practice a table is provided to easily reference and summarize the information.

Design Requirements: The Design requirements section provides all of the information to size the practice for compliance. It provides the design criteria, and sizing equations. In addition, material specifications are provided in this section.

Construction, Protection, and Maintenance Requirements: This section provides the guidelines and requirements for each practice. The design of all practices shall include consideration for maintenance and maintenance access. - A legally binding Inspection, Protection and Maintenance agreement shall be completed for each practice and is described in this section. Per section 450 Stormwater Management of the CRS Coordinator's Manual various stormwater practices that are maintained are eligible to receive credit points.

Table 4.1. Description of Acceptable BMPs

GIP		Description
4.1 Shallow Bioretention		Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Bioretention areas may be designed with an underdrain that returns runoff to the conveyance system or designed without an underdrain to exfiltrate runoff into the soil.
4.2 Rain Garden		Rain gardens are similar to traditional bioretention practices, except their small size allows them to be incorporated into landscaping. Runoff that enters the rain garden is allowed to slowly infiltrate into the subsoil or collected by an underdrain for offsite discharge.
4.3 Water Quality Swale/ Enhanced Swale		Water Quality Swale/Enhanced Swale are vegetated open channels that are designed and constructed to capture and treat storm water runoff within dry or wet cells formed by check dams or other structures.
4.4 Permeable Pavement		Permeable pavement is pavers or pervious concrete or asphalt with void areas that are generally filled with pervious materials. They are designed with an underlying reservoir (stone or manmade products) to temporarily store surface runoff before it infiltrates into the subsoil and/or flows out through an underdrain system.
4.5 Exfiltration Trench		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.
4.6 Rainwater Harvesting		Cisterns are common storm water management practice used to catch rainfall and store it for later use. Typically, gutters and downspout systems are used to collect the water from roof tops and direct it to a storage tank. Rainwater harvesting systems can be either above or below the ground. Once captured in the storage tank, the water may be used for non-potable indoor (requires treatment) and outdoor uses.
4.7 Green Roof		Green roofs represent an alternative to traditional impervious roof surfaces and typically consist of underlying water proofing, drainage systems, and an engineered planting media. Storm water runoff is captured and temporarily stored in the engineered planting media, where it is subjected to evaporation and transpiration before being conveyed back into the storm drain system. There are two different types of green roof systems. Intensive green roofs have a thick layer of soil, can support a diverse plant community, and may include trees. Extensive green roofs have a much thinner layer of soil that is comprised primarily of drought tolerant vegetation.

4.1 SHALLOW BIORENTION

Figure 4.1.1. Bioretention Area integrated into a parking lot design

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	HIGH

Description:
Bioretention areas are vegetated, shallow depressions used to promote absorption and infiltration of runoff. Captured runoff is treated by filtration through an engineered soil medium and is then either infiltrated into the subsoil or exfiltrated through an underdrain.

Variations:
Shallow bioretention areas are a variation that can be used in areas where the water table is high, as it is in much of Cutler Bay. Bioretention areas are constructed without underdrain in soils with measured infiltration rates greater than 0.5 inches per hour and with an underdrain in less permeable soils.

Key Advantages:

- Flexible layout, easy to incorporate in landscaped areas
- Very effective at removing pollutants and reducing runoff volumes
- Generally, one of the more cost-effective stormwater management options
- Relatively low maintenance activities costs
- Can contribute to better air quality and help reduce urban heat island impacts
- Can improve property values and site aesthetics through attractive landscaping
- Habitat creation

Key Limitations:

- May need to be combined with other BMPs to meet the Volume and Flood Attenuation requirement
- May have limited opportunities for implementation due to the amount of open space available or high groundwater

Performance Standard Compliance				
Water Quality				Volume and Flood Attenuation
Total Suspended Solids	Nutrients	Metals	Pathogens	
▶	▶	▶/✓	✓	▶

▶ High ✓ Medium ✕ Low

4.1.1 General Application

Bioretention can be used where stormwater can be conveyed to a surface area. Bioretention systems have been used at commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped. It should be noted that special care shall be taken to provide adequate pre-treatment for bioretention cells in space-constrained high traffic areas. Typical locations for bioretention include the following:

Figure 4.1.2. Bioretention – Before and After Parking Lot Island

Parking lot islands. The parking lot grading is designed for sheet flow towards linear landscaping areas and parking islands between rows of spaces. Curb-less pavement edges can be used to convey water into a depressed island landscaping area. Curb cuts can also be used for this purpose.

Parking lot edge. Small parking lots can be graded so that flows reach a curb-less pavement edge or curb cut before reaching catch basins or storm drain inlets.

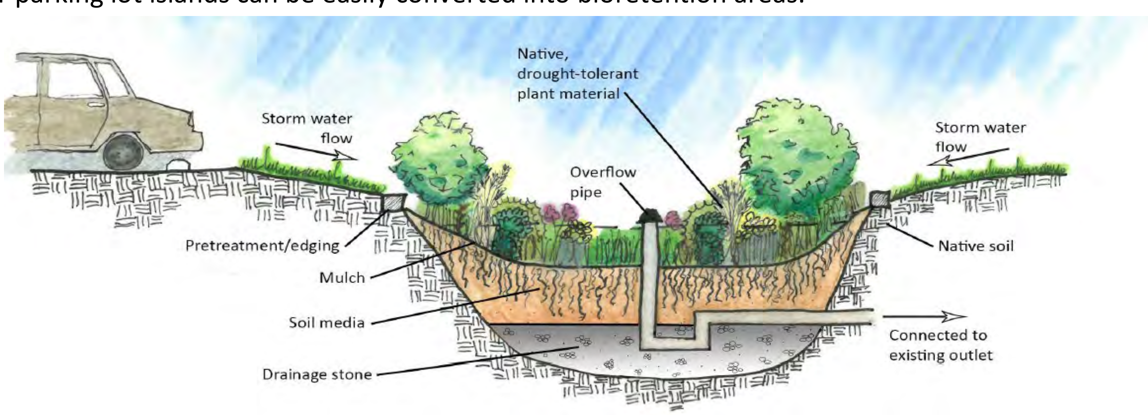
Right of Way or commercial setback. A linear configuration can be used to convey runoff in sheet flow from the roadway, or a grass channel or pipe may convey flows to the bioretention practice.

Courtyards. Runoff collected in a storm drain system or roof leaders can be directed to courtyards or other pervious areas on site where bioretention can be installed.

Unused pervious areas on a site. Storm flows can be redirected from a storm drain pipe to discharge into a bioretention area.

Dry Extended Detention (ED) basin. A bioretention cell can be located on an upper shelf of an extended detention basin, after the sediment forebay, in order to boost treatment.

Retrofitting. Numerous options are available to retrofit bioretention in the urban landscape. Perimeter landscape areas or parking lot islands can be easily converted into bioretention areas.



4.1.2 Planning and Physical Feasibility

Bioretention can be applied in most soils or topography since runoff simply percolates through an engineered soil bed and can be returned to the stormwater system if the infiltration rate of the underlying soils is too low. The following criteria provided in **Table 4.1.1** shall be considered when evaluating the suitability of a bioretention area for a development site.

Table 4.1.1. Bioretention Constraints

Bed Depth	Contributing Drainage Area	Floodplains	Hotspot Land Uses	Hydraulic Head needed	Irrigation or Baseflow	Ponding Depth
Min 24" (Level 1) Min 36" (Level 2) Shallow bioretention can be 12"	0.1-2.5 acres or adequate pre-treatment/treatment train.	Not allowed.	Underdrain required, refer to hotspot guidance.	3' min. Linear, multi-cell systems may also be used.	Avoid access non-stormwater run-on. Irrigate if necessary for survival.	max ponding depth must be less than 12 inches below the overflow structure
Setbacks	**Site Topography Needed**	**Space Needed**	**Soils Requirement**	**Underdrain**	**Utility Requirement**	**Seasonally High Water Table Requirement**
Water supply wells require 100'. Septic systems require 50'. Impermeable barrier required close to structures/ roadways.	Slope greater than 1% and less than 5%. Terracing or other inlet controls may be used to slow runoff velocities.	3-10% of contributin g drainage area.	Relatively high hydraulic conductivity in the surrounding soils, HSG C or D need an underdrain. Infiltration test required.	Shall be tied to ditch or conveyance system.	Consider clearance for all utilities. Min. 5' from down-gradient wet utility lines. Double-cased Dry utility lines may cross under.	Must be at least 0.5 foot below the bottom of the retention area.

The data listed below is necessary for the design of a bioretention area and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of bioretention area.

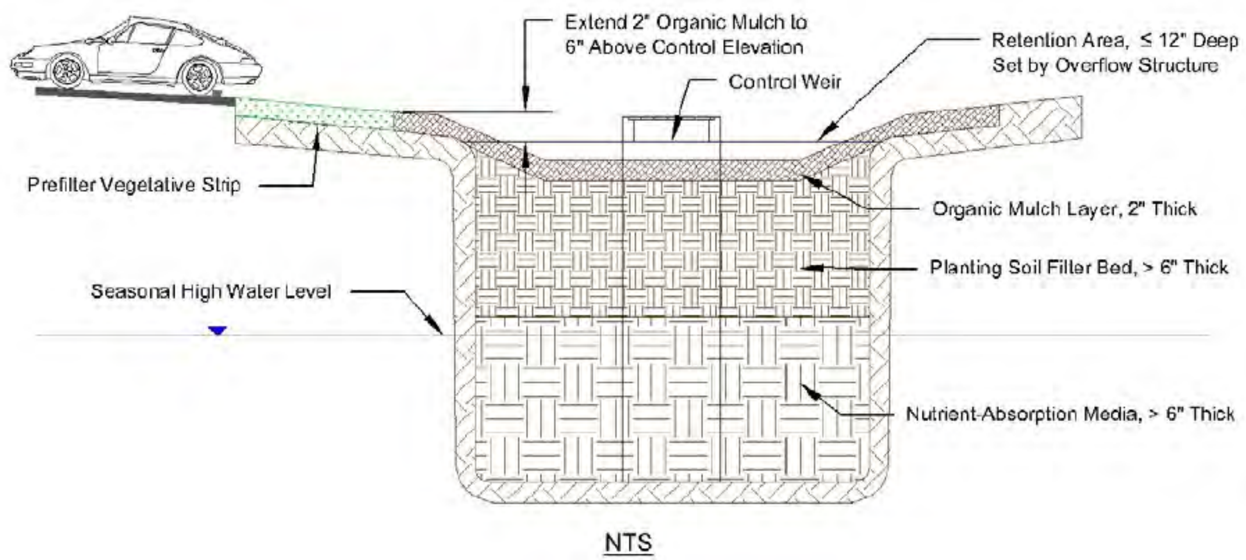
4.1.3 Design Considerations and Requirements

A shallow bioretention system typically consists of several components (see **Figure 4.1.3**). Some of the components are required elements while others are recommendations. These can be seen in **Table 4.1.2.** These criteria should be considered the minimum standards for the design of a shallow bioretention system in Cutler Bay.

Table 4.1.2. Bioretention Design Criteria

Shallow Bioretention Design Criteria	
Required Elements	
Surface Ponding Area/ Retention Area	An area that provides temporary surface storage (less than 12") for runoff before infiltration through the planting soil filter bed.
Dispersion Material	Organic Mulch or Rock Layer; 1"-3" layer between surface ponding and planting media, with benefits including heavy metals, reduced weed establishment, regulation of soil temperature and moisture, and addition of organic matter to the soil. Pre-emergent herbicides may be applied sparingly as needed to further minimize weed establishment.
Planting Media Layer/ Planting Soil Filter Bed	Provides at least 6" of planting media for vegetation within the basin as well as a sorption site for pollutant and a matrix for soil microbes.
Woody Plants, Ornamental Grasses, and Herbaceous Plants	Florida-friendly plants that provide a carbon source for the bioretention system, help facilitate microbial activity, and improve infiltration rates.
Overflow Pipe or Spillway	A structure to allow rainfall events that exceed cell volume capacity to bypass the system. The discharge invert should be set no higher than 12" above the bottom of the surface ponding area. Conveyance of the excess runoff should include downstream erosion-control measures if necessary.
Recommended Elements	
Pre-filter Strip	Between the contributing tributary area and the surface ponding area to capture coarse sediments and reduce sediment loading to the ponding area. May provide other measures to minimize e the sediments entering the system in lieu of a prefilter strip.
Nutrient-Sorption Media	A 6" layer below the planting media or incorporated within the plant media to a depth of 12", which promotes pollutant through sorption and denitrification.
Energy-Dissipation Mechanism	For concentrated flow, a structure that reduces runoff velocities, distributes flow, and reduces disturbance of the mulch layer.

Figure 4.1.3. Cross Section View of a Shallow Bioretention System



Location and Planning

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

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

Design Requirements

Discharge Requirements

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

Recovery Requirements

The retention volume used to estimate the average annual load reduction must be recovered in less than 72 hours under seasonal high water table (SHWT) conditions.

A Florida registered Professional Engineer must perform a recovery analysis using site-specific geotechnical data to determine storage recovery. For guidance on the number of borings refer to SJ93-SP10 (SJRWMD, 1993).

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

Pre-filter Strip

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

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

Retention Area/Surface Ponding Area

- The maximum ponding depth must be less than 12 inches below the overflow structure or top of bioretention cell.
- The recovery time must be less than 72 hours under SHWT conditions.

Dispersion Layer/Organic Mulch Layer

- The surface dispersion or organic mulch layer must be 1-3 inches deep and cover the surface of the basin to above to the expected high water line
- For continuing maintenance, the depth must not exceed 4 inches or soil aeration may be reduced.
- Hardwood mulch must be used due to its higher pH, improved microbial activity, and slower decomposition rate. Examples of acceptable mulches are those made from melaleuca or eucalyptus trees. Pine bark or pine straw is not acceptable. Inorganic mulches such as rocks or recycled rubber may also be used.
- Partially composted mulch is acceptable, especially in the lower parts of the depression as this will reduce the tendency of the mulch to float.

Planting Soil Filter Bed/Planting Media Layer

- The planting media layer must be at least 6” thick.
- The bed material must be sandy loam, loamy sand, or loam texture.
- The media density should be no greater than 70 pounds/cubic foot dry and contain at most 10% organics.
- Clay content should be between 3% and 5%.
- Planting media pH should reflect an optimum range for the plants in between 5.5 and 7.5.
- Planting organic matter content must be between 3% and 10% by volume. Soil amendments to raise the organic matter content must have a carbon to nitrogen ratio of at least 50%
- The planting media must be uniform and free or stone, stumps, roots, or other similar material greater than 2” in size.

Nutrient-Sorption Layer

- The nutrient-sorption layer should be at least 6” thick or mixed with the plant media mix.
- The unit weight of layer media should be more than 80 pounds per cubic foot when dry.
- Greater than 15% but less than 30% of the particles in the layer media should pass the #200 sieve.
- The media should be more than 50% uniformly graded sand by volume and the material should not contain shale.
- The media water-holding capacity should be at least 35% as measured by porosity.
- At the specified unit weight noted above, the vertical permeability must be at least 0.08 inch per hour but less than 0.25 inch per hour.
- The media must have an organic content of at least 5% by volume. The organic content must be evenly distributed throughout the layer.
- The media pH should be between 6.5 and 8.0.
- The concentration of soluble salts should be less than 3.5 g (KCL)/L.
- The sorption capacity of the sand should exceed 0.005 mg OP/mg media.
- The residual moisture content should exceed 50% of the porosity.

Water Quantity Credits

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

- Calculating the Curve Number (CN) for the bioretention area and including this in the area weighted CN for the entire site.
- Explicitly modeling the hydraulic function of the bioretention system and its overflow control structure.

Maintenance Access

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

Safety Features

Shallow bioretention systems generally do not require any special safety features. However, all Florida Department of Transportation and Cutler Bay safety requirements must be met where applicable. Fencing these facilities is not generally desirable. Railings or a grate can be used to address safety concerns if the area is designed with vertical walls. Roadway curbs and curb cuts may be considered as part of the design and should be consistent with the most recent FDOT Specifications for Road and Bridge Construction.

Landscaping

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

Landscaping of Catchment

- The unpaved contributing area should be well vegetated to minimize erosion and sediment inputs to the bioretention system.
- Where feasible a prefilter vegetative strip of vegetative swale should be installed.
- If used, trees should be spaced 12 to 15 feet apart depending on the type.
- Plants should be placed at irregular intervals.
- If woody vegetation is used, it should be placed along the banks and edges of the bioretention system, no in the direct flow path.
- Only species well adapted to the regional climate should be used.
- Species planted in well-drained media should be tolerant of short-term ponding as well as periods of low soil moisture.
- Vegetation must conform to regulations regarding line of sight.

4.1.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this Manual.

Requirements DURING Construction

- Construction equipment shall be restricted from the bioretention area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before stormwater can be accepted into the bioretention area. This will prevent sediment from clogging the pores in the planting media.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of BMP locations during construction of a land development will ensure that native soils that surround (or are within) the stormwater treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of BMP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the BMP shall be permanently stabilized. Regardless, a lack of BMP protection will most certainly reduce or destroy the stormwater functionality of the BMP once it is installed, often leading to costly corrective actions required by the Town.

Protection Requirements

- Provide signage for the BMP.
  - Allows for easy identification and location of the BMP.
  - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
  - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the stormwater treatment area.
- Design the layout of the bioretention area such that maintenance access can be achieved without the need for vehicles or equipment in the stormwater treatment area.
- Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the stormwater treatment areas.

Inspection Requirements

- Inspect the areas where stormwater flows into or out of the bioretention area for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.

- Inspect the property that drains to the bioretention area for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect bioretention area (and any pre-treatment areas) for sediment build up, erosion, vegetative health/conditions, etc., Perform appropriate maintenance as necessary.
- Inspect underdrain cleanout to ensure stormwater infiltrates properly. Clean-out underdrain if necessary.

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4.2 RAIN GARDENS

Figure 4.2.1. Rain Gardens can be designed to blend with a building's landscaping.

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	MODERATE

Description:
Rain gardens are small retention basins that can be integrated into a site's landscaping. A rain garden is a shallow, constructed depression that is planted with native plants. They are used in order to receive stormwater from impervious surfaces and then allow this water to naturally infiltrate into the ground.

Variations:
Rain gardens can be designed as retrofits.

Key Advantages:

- Reduced runoff volume
- Provides ground water recharge
- Reduced TSS
- Reduced pollutant loading
- Habitat creation
- Enhanced site aesthetics

Key Limitations:

- Small contributing drainage area
- Cannot construct within 50 feet of a public or private potable water supply well or within 15 feet of an onsite wastewater disposal and treatment system
- Must have appropriate soil and conditions for infiltration

Performance Standard Compliance				
Water Quality				Volume and Flood Attenuation
Total Suspended Solids	Nutrients	Metals	Pathogens	
High	High	High	High	High

▶ High ✓ Medium ✗ Low

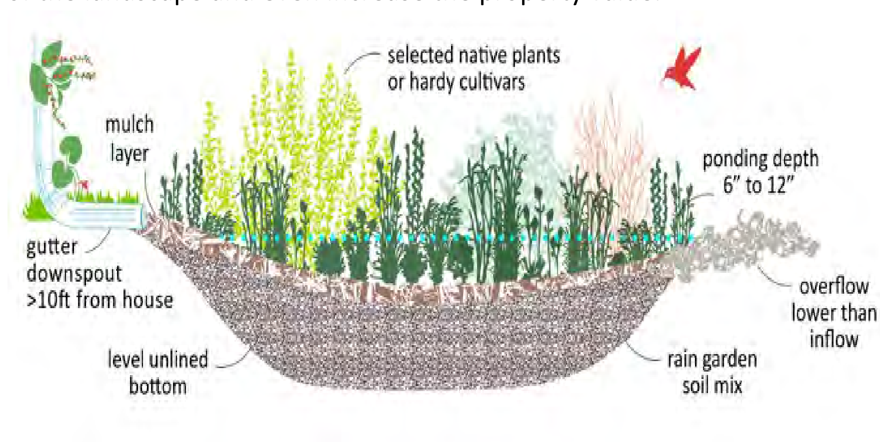
4.2.1 General Application

Figure 4.2.2. Example Rain Gardens

Rain gardens are only small retention basins; however, they are very beneficial in terms of stormwater and ground water. They function as a BMP by recharging the local aquifers to increase the amount of stormwater that infiltrates into the ground. Two more functions of rain gardens include decreasing the amount of pollutants that enter nearby bodies of water and conserving municipal water resources by reducing the need for potable water irrigation.

Another benefit of rain gardens is their ability to blend into the natural landscape and even create more habitats for birds, butterflies, and beneficial insects. In addition, the native plants that are selected for the rain garden have the ability to increase the appeal of the landscape and even increase the property value.

Rain gardens can be placed in many different locations as they will slow down the rush of water from impervious surfaces such as streets, roofs, sidewalks, parking areas, etc. Then regardless of the size of the rain garden it will hold the water and slowly filter it into the groundwater.



Typical Cross Section of a Rain Garden

4.2.2 Planning and Physical Feasibility

Rain gardens can be applied in most soils or topography since runoff simply percolates through an engineered soil bed and can be returned to the storm water system if the infiltration rate of the underlying soils is too low. The following criteria provided it **Table 4.2.1** shall be considered when evaluating the suitability of a rain garden for a development site.

Table 4.2.1. Rain Garden Constraints

Contributing Drainage Area	Ponding Depth	Location	Topography	Soil Requirements	Water Table Requirement	Plants
Less than 3 acres.	4" min. 10" max	At least 10 feet away from a structure. Not over a septic field.	Naturally occurring low spot.	Amended soils or rain garden soil mix required	2' of separation	Must be appropriate for dry and wet conditions.

The data listed below is necessary for the design of an urban bioretention area and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of rain garden or assume a HSG D soil with an underdrain.

4.2.3 Design Requirements

Since rain gardens are small bioretention areas, they follow a lot of the same design criteria as a bioretention area. However, rain gardens are typically sized on a smaller scale and for a smaller area. Design criteria for rain gardens is detailed in **Table 4.2.2**.

Table 4.2.2. Rain Garden Design Criteria

Rain Garden Design Criteria
Need to recover the required treatment volume within 24 to 36 hours to prevent damage to vegetation.
The seasonal high groundwater table shall be at least 2 feet beneath the bottom of the rain garden
The sides and bottom of the rain garden shall be stabilized with vegetative cover
Shall not be constructed within 50 feet of a public or private potable water supply well of within 15 feet of an onsite wastewater disposal and treatment system
The rain garden shall not be within 5 feet of the right-of-way
Maximum contributing drainage area: less than 3 acres
Ponding Depth: min. of 4” and max of 10”
Plants: Florida-Friendly; can grow in wet and dry conditions
Soil/media mixtures includes 6”-12” of compost

Rain Garden Planting Plan

The degree of landscape maintenance that can be provided will determine some of the planting choices for rain gardens. The planting cells can be formal gardens or naturalized landscapes.

In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a “turf and trees” landscaping model. Spaces for herbaceous flowering plants can be included. This may be attractive at a community entrance location.

Native plants or shrubs are preferred for rain gardens, although some ornamental species may be used. As with other BMPs, selected perennials, shrubs, and trees shall be tolerant of drought and inundation. The landscape designer shall also take into account that de-icing materials may accumulate in the rain gardens in winter and could kill vegetation. Additionally, tree species selected shall be those that are known to survive well in the compacted soils and polluted air and water of an urban landscape.

4.2.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this manual.

Requirements DURING Construction

- Construction equipment shall be restricted from the rain garden area to prevent sedimentation and compaction of the native soils.
- Ensure design infiltration is met after construction.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the urban bioretention area. This will prevent sediment from clogging the pores in the planting media.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of BMP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of GIP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the BMP is permanently stabilized. Regardless, a lack of BMP protection will most certainly reduce or destroy the storm water functionality of the BMP once it is installed often leading to costly corrective actions required by the Town.

Protection Requirements

- Provide signage for the BMP.
  - Allows for easy identification and location of the BMP.
  - Serves as a general education tool, making those responsible for property, landscape, or BMP maintenance and the general public aware of the water quality features of the BMP and to avoid encroachment.
  - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the rain garden area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect rain gardens at the beginning and the end of each rainy season
- Inspect the areas where storm water flows into or out of the rain garden for clogging or sediment buildup.

- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.
- Inspect the property that drains to the rain garden for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health; replace if necessary.
- Keep inlets clear of debris to prevent clogging; clear if necessary.
- Inspect rain garden area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.
- Inspect underdrain cleanout to ensure storm water infiltrates properly. Clean-out underdrain if necessary.

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4.3 WATER QUALITY SWALE/ENHANCED SWALE

Figure 4.3.1. Example of Dry Water Quality Swale

Description:
Vegetated open channels designed to capture and infiltrate stormwater runoff within a dry storage layer beneath the base of the channel.

Variations:
- Dry water quality swale
- Enhanced swale
- Treatment Swale

Key Advantages:
- Stormwater treatment combined with conveyance
- Less expensive than curb and gutter
- Reduces runoff velocity
- Promotes infiltration

Key Limitations:
- Higher maintenance than curb and gutter
- Cannot be used on steep slopes
- High land requirement
- Requires 3 feet of head
- Must have appropriate soil and groundwater table conditions for infiltration

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	LOW
Ground-Level Encroachment	MODERATE
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

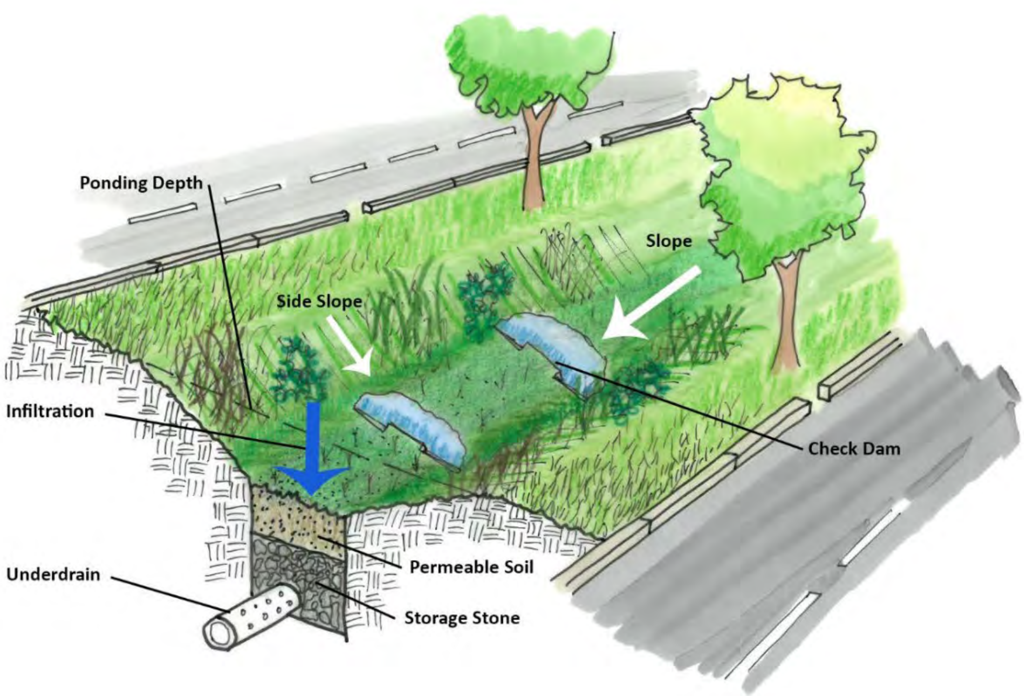
Performance Standard Compliance				
Water Quality				
Total Suspended Solids	Nutrients	Metals	Pathogens	Volume and Flood Attenuation
✓/▶	✓/▶	✓/▶	✓/▶	✓/▶

▶ High ✓ Medium ✕ Low

4.3.1 General Application

Water quality swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface materials (other than mulch and ornamental plants). The water quality swale is a soil filter system that temporarily stores and then filters the desired water quality volume. Water quality swales rely on a pre-mixed soil media filter below the channel that is similar to that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. Otherwise, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale, beneath the filter media. Water quality swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping with native plants. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Figure 4.3.2. Water Quality Swale Section



4.3.2 Planning and Physical Feasibility

Water quality swales can be implemented on a variety of development sites where density and topography permit their application. The following criteria provided in **Table 4.3.1** shall be considered when evaluating the suitability of a dry water quality swale/enhanced swale for a development site.

Table 4.3.1. Dry Water Quality Swale/Enhanced Swale Constraints

Community Acceptance	Contributing Drainage Area	Hotspot Land Uses	Hydraulic Capacity	Location	Irrigation or Baseflow	Setbacks
Concerns such as grass/landscape maintenance/ mowing, standing water, and mosquitoes shall be addressed though the design process and proper on-going operation and routine maintenance.	2.5 acres max. For larger drainage areas, a series of inlets and diversions are required to prevent high velocity and erosion in the channel.	Impermeable liner required.	Level 1 water quality swales shall convey the 100-yr. storm at non-erosive velocities and contain the 10-yr. storm within banks.	Cannot be within 50 feet of a public or private water supply well or within 15 feet of an onsite wastewater disposal and treatment system.	Avoid access non-stormwater run-on.	1’ min from roadbed invert.
Soils Requirement	**Space Needed**	**Underdrain**	**Topography**	**Utility Requirement**	**Water Table Requirement**	**Hydraulic Head Needed**
Infiltration rates ≤ 0.5” per hour require underdrain. Infiltration test required. Must have SHGWT conditions for infiltration.	3-10% of contributing drainage area, depending on the amount of impervious cover.	Shall be tied to ditch or conveyance system.	2-4% longitudinal slopes. Check dams can reduce the effective slope of the swale and enhance filtering and/or infiltration. Steeper slopes adjacent to the swale shall be avoided to prevent runoff velocities that may carry a high sediment load.	Water/sewer lines shall be placed under pavement. Other utilities under BMP require double casing or other special protection.	2’ of separation	3’ min.

The data listed below is necessary for the design of a dry water quality swale/enhanced swale and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed invert elevation.

4.3.3 Design Requirements

Swales can be oriented to accept runoff from a single discharge point, or to accept runoff as lateral sheet flow along the swale's length. Design criteria for enhanced swale/water quality swale are detailed in **Table 4.3.2**.

Table 4.3.2. Enhanced Swale/Water Quality Swale Design Criteria

Design Criteria
The storage depth is the sum of the Void Ratio (V_r) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth.
Bottom of swale should be at least 2 feet wide to facilitate moving
Effective swale slope ≤2%
Media Depth minimum = 18 inches; recommended maximum = 36 inches
Sub-soil testing: one per 50 linear feet, 2 minimum; not needed if an underdrain is used; min. infiltration rate shall be > 0.5 inch/hour to remove the underdrain requirement.
Underdrain: Schedule 40 PVC or HDPE with clean-outs. Underdrain & Underground Storage Layer
Media: supplied by the vendor or mixed onsite.
Inflow: sheet or concentrated flow with appropriate pre-treatment
Pre-Treatment: a pre-treatment cell, spreader, or another approved (manufactured) grass filter strip, gravel diaphragm, or gravel flow pre-treatment structure.
On-line design or Off-line design or multiple treatment cells.
Planting Plan: turf grass, tall meadow grasses, native herbaceous cover, or trees

Figure 4.3.3. Example of Dry Water Quality Swale in an Urban/Office Setting

Soil Infiltration Rate Testing

The second key sizing decision is to measure the infiltration rate of subsoils below the water quality swale area to determine if an underdrain will be needed. The infiltration rate of the subsoil shall exceed 0.5 inches per hour to avoid installation of an underdrain.

Water Quality Swale Geometry

Design guidance regarding the geometry and layout of water quality swales is provided below.

Shape. A parabolic shape is preferred for water quality swales for aesthetic, maintenance, and hydraulic reasons. However, the design may be simplified with a trapezoidal cross-section, as long as the soil filter bed boundaries lay in the flat bottom areas.

Side Slopes. The side slopes of water quality swales shall be no steeper than 3H:1V for maintenance considerations (i.e., mowing). Flatter slopes are encouraged where adequate space is available to enhance pre-treatment of sheet flows entering the swale. Swales shall have a bottom width from 2 to 8 feet to ensure that an adequate surface area exists along the bottom of the swale for filtering. If a swale will be wider than 8 feet, the designer shall incorporate berms, check dams, level spreaders, or multi-level cross-sections to prevent braiding and erosion of the swale bottom.

Swale Longitudinal Slope. The longitudinal slope of the swale shall be moderately flat to permit the temporary ponding of the Treatment Volume within the channel. The recommended swale slope is less than or equal to 1-2%.

Check dams: Check dams shall be firmly anchored into the side-slopes to prevent outflanking and be stable during the 10-year storm design event. The height of the check dam relative to the normal channel elevation shall not exceed 12 inches. Each check dam shall have a minimum of one weep hole or a similar drainage feature, so it can dewater after storms. Armoring may be needed behind the check dam to prevent erosion. The check dam shall be designed to spread runoff evenly over the water quality swale's filter bed surface, through a centrally located depression with a length equal to the filter bed width. In the center of the check dam, the depressed weir length shall be checked for the depth of flow and sized for the appropriate design storm. Check dams shall be constructed of wood, stone, or concrete.

Ponding Depth: Drop structures or check dams can be used to create ponding cells along the length of the swale. The maximum ponding depth in a swale shall not exceed 12 inches at the most downstream point.

Drawdown: Water quality swales shall be designed so that the desired Treatment Volume is completely filtered within 24 hours or less. This drawdown time can be achieved by using the soil media mix specified in Section 6.6 and an underdrain along the bottom of the swale, or native soils with adequate permeability, as verified through testing.

Underdrain: Underdrains are provided in water quality swales to ensure that they drain properly after storms. The underdrain shall be constructed of 6-inch diameter perforated HDPE or PVC, which is placed on either a 3-inch layer of double-washed gravel. The underdrain shall be encased in a gravel layer extending at least 3 inches above the surface of the pipe. This gravel layer shall be covered with a 3-inch layer of choker stone (FLDOT #8 or #89), which is then covered with a permeable geotextile.

Pre-Treatment

Several pre-treatment measures are feasible, depending on whether the specific location in the water quality swale system will be receiving sheet flow, shallow concentrated flow, or fully concentrated flow:

- **Initial Sediment Forebay (channel flow).** This grass cell is located at the upper end of the water quality swale segment with a 2:1 length to width ratio and a storage volume equivalent to at least 15% of the total Treatment Volume.
- **Check Dams (channel flow).** These energy dissipation devices are acceptable as pre-treatment on small swales with drainage areas of less than 1 acre.
- **Tree Check Dams (channel flow).** These are street tree mounds that are placed within the bottom of a water quality swale up to an elevation of 9 to 12 inches above the channel invert. One side has a gravel or river stone bypass to allow storm runoff to percolate through.
- **Grass Filter Strip (sheet flow).** Grass filter strips extend from the edge of the pavement to the bottom of the water quality swale at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) slope and 3:1 or flatter side slopes on the water quality swale.
- **Gravel Diaphragm (sheet flow).** A gravel diaphragm located at the edge of the pavement shall be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4-inch drop. The stone shall be sized according to the expected rate of discharge.
- **Pea Gravel Flow Spreader (concentrated flow).** The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points and shall have a 2 to 4-inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel shall extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the swale.

Conveyance and Overflow

The bottom width and slope of a water quality swale shall be designed such that the velocity of flow from a 1-inch rainfall will not exceed 3 feet per second. Check dams may be used to achieve the needed runoff reduction volume, as well as to reduce the flow. Check dams shall be spaced based on channel slope and ponding requirements, consistent with the criteria in **Table 4.3.3**.

The swale shall also convey the 2- and 10-year storms at non-erosive velocities with at least 6 inches of freeboard. The analysis shall evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams.

Water quality swales may be designed as off-line systems, with a flow splitter or diversion to divert runoff in excess of the design capacity to an adjacent conveyance system. Or, strategically placed overflow inlets may be placed along the length of the swale to periodically pick up water and reduce the hydraulic loading at the downstream limits.

Filter Media: Water quality swales require replacement of native soils with a prepared soil media. The soil media provides adequate drainage, supports plant growth, and facilitates pollutant removal within the water quality swale. At least 18 inches of soil media shall be added above the choker stone layer to create an acceptable filter. The mixture for the soil media is identical to that used for bioretention (GIP-3) (refer to Appendix D for additional soil media specifications).

Underdrain and Underground Storage Layer: Some Level 2 water quality swale designs will not use an underdrain (where soil infiltration rates are > 0.5 inch/hour). For Level 2 designs with an underdrain, an underground storage layer, consisting of a minimum 12 inches of stone, shall be incorporated below the invert of the underdrain. The depth of the storage layer will depend on the target treatment and storage volumes needed to meet water quality criteria. However, the bottom of the storage layer shall be at least 2 feet above the seasonally high groundwater table and bedrock. The storage layer shall consist of clean, washed #57 stone or an approved infiltration module.

A water quality swale shall include cleanout pipes along the length of the swale if the contributing drainage area exceeds 1 acre. The cleanout point shall be tied into any T's or Y's in the underdrain system and shall extend upwards to be flush with surface, with a vented cap.

Landscaping and Planting Plan: Designers shall choose grasses, herbaceous plants or trees that can withstand both wet and dry periods and relatively high velocity flows for planting within the channel. Salt tolerant grass species shall be chosen for water quality swales receiving drainage from areas treated for ice in winter. Taller and denser grasses are preferable, although the species is less important than good stabilization and dense vegetative cover. Grass species shall have the following characteristics: a deep root system to resist scouring, a high stem density with well-branched top growth, water-tolerance, resistance to being flattened by runoff, and an ability to recover growth following inundation. A qualified landscape designer shall be consulted for selection of appropriate plantings.

Water Quality Swale Material Specifications

Table 4.3.3 outlines the standard material specifications for constructing water quality swales.

Table 4.3.3. Water Quality Swale Material Specifications

Material	Specification	Notes
Filter Media Composition	Filter Media to contain (by volume): 30-70% sand < 40% silt 5-10% organic matter < 20% clay.	The volume of filter media is based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	Mix on-site or procure from an approved media vendor.	
Filter Fabric	A non-woven polyprene geotextile with a flow rate of > 110 gal./min./sq. ft. (e.g., Geotex 351 or equivalent); Apply immediately above the underdrain only.	
Choking Layer	A 3-inch layer of choker stone (typically #8 or # 89 washed gravel) laid above the underdrain stone.	
Stone and/or Storage Layer	A 12 to 18-inch layer (depending on the desired depth of the storage layer) of #57 stone shall be double-washed and clean and free of all soil and fines.	
Underdrains and Cleanout Points	6-inch PVC or HDPE pipe, with 3/8-inch perforations.	If needed, install perforated pipe for the full length of the water quality swale. Use non-perforated pipe, as needed, to connect with the storm drain system.
Vegetation	Plant species as specified on the landscaping plan.	
Check Dams	Use non-erosive material such as wood, gabions, riprap, or concrete. All check dams shall be underlain with filter fabric and include weep holes. Wood used for check dams shall consist of pressure-treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak, or locust.	
Erosion Control Fabric	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least 2 growing seasons.	

4.3.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this manual.

Requirements DURING Construction

- Construction equipment shall be restricted from the dry water quality swale/enhanced swale area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before stormwater can be accepted into the dry water quality swale/enhanced swale. This will prevent sediment from building up in the BMP.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of BMP locations during construction of a land development will ensure that native soils that surround (or are within) the stormwater treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of BMP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the BMP shall be permanently stabilized. Regardless, a lack of BMP protection will most certainly reduce or destroy the stormwater functionality of the BMP once it is installed, often leading to costly corrective actions required by the Town.

Protection Requirements

- Provide signage for the BMP.
  - Allows for easy identification and location of the BMP.
  - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
  - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the stormwater treatment area.
- Design the layout of the dry water quality swale/enhanced swale such that maintenance access can be achieved without the need for vehicles or equipment in the stormwater treatment area.
- Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the stormwater treatment areas.

Inspection Requirements

- Inspect the areas where stormwater flows into or out of the dry water quality swale/enhanced swale for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.

- Inspect the property that drains to the dry water quality swale/enhanced swale for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect dry water quality swale/enhanced swale area for sediment build up, erosion, vegetative health/conditions, etc. Perform appropriate maintenance as necessary.
- Inspect underdrain cleanout to ensure stormwater infiltrates properly. Clean-out underdrain if necessary.

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4.4 PERVIOUS PAVEMENT SYSTEMS

Figure 4.4.1. Permeable Pavement incorporated into sidewalk design

DEVELOPMENT ATTRIBUTES

Construction Cost — HIGH

Operation and Maintenance Cost — HIGH

Ground-Level Encroachment — HIGH

Building Footprint Enhancement — MODERATE

Triple Bottom-Line Benefits — MODERATE

Description:
Permeable pavements allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored (functioning as a retention system) and/or infiltrated. Porous paving systems have several design variants. The four major categories are: 1) pervious concrete; 2) modular block systems; 3) grass pavers; and 4) gravel pavers. All have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer, and a filter layer or fabric installed on the bottom.

Variations:
Variations include permeable interlocking pavers, concrete grid pavers, Flexi pave, and plastic reinforced grid pavers.

Key Advantages:

- Runoff volume reduction
- Can increase aesthetic value
- Provide water quality treatment

Key Limitations:

- High cost and maintenance requirements
- Limited to low traffic areas with limited structural loading
- Potential issues with handicap access
- Infiltration can be limited by underlying soil properties
- May not be appropriate on sites with high wind blown sediment loading

Performance Standard Compliance				
Water Quality				Volume and Flood Attenuation
Total Suspended Solids	Nutrients	Metals	Pathogens	
▶	✓/ ▶	▶	NA	✓/ ▶

▶ High ✓ Medium ✗ Low

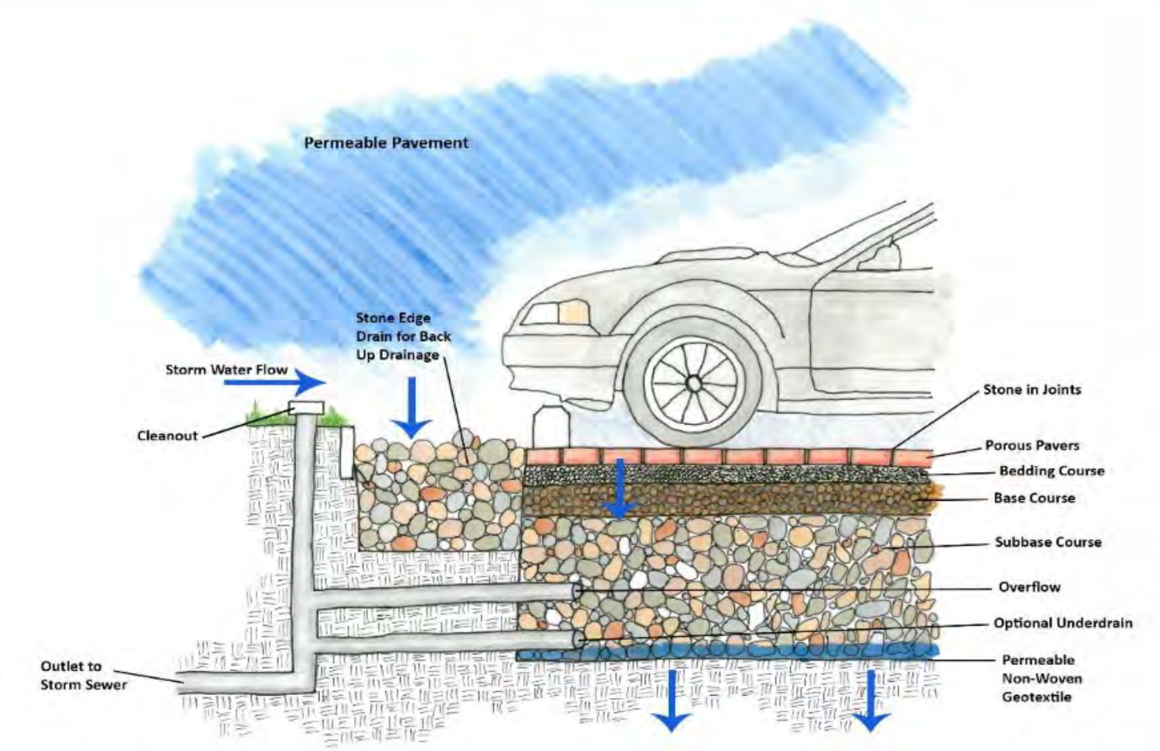
4.4.1 General Application

Figure 4.4.2. Permeable Pavement installed in a parking lot application

Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Permeable pavements consist of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.

The thickness of the reservoir layer is determined by both a structural and hydrologic design analysis. The reservoir layer serves to retain stormwater and also supports the design traffic loads for the pavement. In low-infiltration soils, some or all of the filtered runoff is collected in an underdrain and returned to the storm drain system. If infiltration rates in the native soils permit, permeable pavement can be designed without an underdrain to enable full infiltration of runoff. A combination of these methods can be used to infiltrate a portion of the filtered runoff.

Permeable pavement is typically designed to treat stormwater that falls on the actual pavement surface area, but it may also be used to accept run-on from small adjacent impervious areas, such as impermeable driving lanes or rooftops. However, careful sediment control is needed for any run-on areas to avoid clogging of the down-gradient permeable pavement. Permeable pavement has been used at commercial, institutional, and residential sites in spaces that are traditionally impervious. Permeable pavement promotes a high degree of runoff volume reduction and nutrient removal, and it can also reduce the effective impervious cover of a development site.



4.4.2 Planning and Physical Feasibility

Since permeable pavement has a very high runoff reduction capacity, it should always be considered as an alternative to conventional pavement. Permeable pavement is subject to the same feasibility constraints as most infiltration practices. The following criteria provided in **Table 4.4.1** shall be considered when evaluating the suitability of permeable pavement for a development site.

Table 4.4.1. Permeable Pavement Constraints

Available Space	Contributing Drainage Area	High Loading Situations	Hotspot Land Uses	Hydraulic Head needed	Irrigation or Baseflow	Pavement Slope
Additional space not required	Runoff to permeable pavement shall not exceed twice the surface area of the permeable pavement, and it shall be as close to 100% impervious as possible.	Not intended to treat sites with high sediment or trash/debris loads.	Generally not allowed	2-4 feet if underdrain is used. Otherwise, minimal head required.	Avoid access non-stormwater run-on.	Steep slopes can reduce the stormwater storage capability of and cause shifting of surface and base materials. A terraced design can be used in sloped areas, especially when the local slope is several percent or greater.
Underdrain	**Soils Requirement**	**Setbacks**	**Utility Requirement**	**Water Table Requirement**		
Min. 0.5% slope	HSG C or D need an underdrain. Infiltration test required. Fill soils require a liner.	Water supply wells require 50'. Septic systems require 15'. Not allowed in right of way.	Consider clearance for all utilities. Min. 5' from down-gradient wet utility lines.	2' of separation		

The data listed below is necessary for the design of permeable pavement areas and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of permeable pavement area.

4.4.3 Design Requirements

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.

Structural Design

This document only provides requirements pertaining to the hydraulic functioning of pervious pavement. Therefore, the applicant should be diligent in determining if the application of the pervious pavement system is appropriate for the design's structural capacity and not be subject to premature deterioration failure.

Hydraulic Design

For a pervious pavement area to be permitted as part of the stormwater treatment system, a Florida registered Professional Engineer must demonstrate that the pervious pavement meets all the following hydraulic requirements:

- Pervious pavement systems shall not be constructed within 50 feet of a public or private potable water supply well or within 15 feet of an onsite wastewater disposal and treatment system.

Infiltration and Storage Requirements

- The surface must be maintained to prevent significant clogging and improve infiltration rates. A pervious pavement system infiltration rate of at least 1.5 inches per hour is required in addition to exfiltration to the parent soil providing adequate drawdown shown in the recovery analysis. To show consistency with permit requirements, tests must be conducted within 24 months in August or September and be certified by a Florida registered Professional Engineer. The Designated Responsible Entity must retain test results for 7 years and should submit an electronic copy to Cutler Bay or its successor.
- At least two (maximum of 10 for a site) testing locations per acre must be installed into the pervious pavement system to measure the surface infiltration rates of the pervious pavement system. An example of a device that has been shown to be effective is the Embedded Ring Infiltrometer Kits (ERIKs – Wanielista and Chopra, 2007).
- Sloping pervious pavement surfaces must be minimized. It is recommended – but not mandated – for parking lots and vehicular traffic areas with pervious pavement to be flat and not to exceed a slope of 0.5-1%. Sidewalks, walking, cycling, and cart paths are permitted to have slopes not exceeding 5%. No volume above the lowest elevation of a sloped pervious pavement surface must be included in the pervious pavement system storage volume.
- Parking lots and other vehicular traffic areas (excluding road right of way, pedestrian walks, and bicycle paths) must be constructed to produce 2 inches of nuisance ponding above the surface or above the lowest surface elevation of a sloped surface before overflow is permitted. *Nuisance ponding* is non-hazardous ponding designed to provide a visible warning that the pervious pavement system has failed and that remediation will be required.
- A 1-inch nutrient absorption layer must be installed between the pervious pavement system and the parent soil (excluding sidewalks, walking, cycling, and cart paths).
- The infiltration rate of the parent soil is essential to the function of the pervious pavement system. If the parent soil has a low infiltration rate and the compaction of the predevelopment soil exceeds 95% Modified Proctor Density, the soil must be scarified to a minimum depth of 16 inches, re-graded, and proof rolled to a maximum of 95% Modified Proctor Density.

- Edge restraints must be installed around pervious pavement areas to prevent failure along surface edges and to impede horizontal movement of water below the pavement surface. The edge restraints must extend to the bottom of the reservoir materials.
- The minimum vertical hydraulic conductivity of the pervious pavement system shall not be less than 2.0 inches per hour. The percolation rate of the subgrade soils can be as low as 0.5 inch/hour when the pervious pavement system includes a reservoir of at least 6 inches of rock below the pavement.

Discharge Requirements

- For flood control, the pervious pavement system storage available after a 36 hour drawdown time can be used in the flood control calculation. The Applicant can account for this storage by including the available storage as soil storage in the sites weighted CN or accounting for this storage into the available pond storage for the site.
- Appropriate downstream detention must be provided if a pervious pavement system cannot provide sufficient runoff reduction to meet its flood control requirements.
- Appropriate downstream erosion controls must be provided for potential pavement discharge.

Recovery Requirements

- Outlet structures must allow for 2 inches of nuisance ponding for parking lots and vehicular traffic areas (excluding road right of ways, pedestrian walks, and bicycle paths).
- The SHWT must be at least 12 inches below the bottom of the pervious pavement system profile (excluding the nutrient-absorption layer).
- The storage volume used to estimate the average annual load reduction must be recovered within 72 hours under SHWT conditions.
- The storage volume used to determine the CN or Rational C calculation (for flood-control credit) must be recovered within 36 hours under SHWT conditions.
- A Florida registered Professional Engineer must perform a recovery analysis of the parent soil using site-specific geotechnical data to determine storage recovery. For guidance on the number of borings refer to SJ93-SP10 (SJRWMD 1993).
- A safety factor of 2.0 or more must be applied to the recovery analysis to allow for geological uncertainties. This can be achieved by dividing the measured soil hydraulic conductivity rate by the safety factor or demonstrating recovery within 36 hours.

Underdrain and Underground Storage Layer

The use of underdrains is recommended when there is a reasonable potential for infiltration rates to decrease over time, when underlying soils have an infiltration rate of 0.5 inches per hour or less, when shallow bedrock is present, or when soils must be compacted to achieve a desired Proctor density. Underdrains can also be used to manage extreme storm events to keep detained stormwater from backing up into the permeable pavement.

- An underdrain(s) shall be placed within the reservoir and encased in 8 to 12 inches of clean, washed stone.
- The underdrain outlet can be fitted with a flow-reduction orifice as a means of regulating the stormwater detention time. The minimum diameter of any orifice shall be 0.5 inch.
- An underdrain(s) can also be installed and capped at a downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

Permeable Pavement Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. **Table 4.4.2** describes general material specifications for the component structures installed beneath the permeable pavement. **Table 4.4.3** provides specifications for general categories of permeable pavements. Designers shall consult manufacturer's technical specifications for specific criteria and guidance.

Table 4.4.2. Material Specifications for Underneath the Pavement Surface

Material	Specification	Notes
Bedding Layer	Pervious Concrete: None Interlocking Pavers: 2 in. depth of No. 8 stone over 3 to 4 inches of No. 57	ASTM D448 size No. 8 stone (e.g. 3/8 to 3/16 inch in size). Shall be double-washed and clean and free of all fines.
Reservoir Layer	Pervious Concrete: No. 57 or No. 2 stone Interlocking Pavers: No. 57 or No. 2 stone	ASTM D448 size No. 57 stone (e.g. 1 1/2 to 1/2 inch in size); No. 2 Stone (e.g. 3 inch to 3/4 inch in size). Depth is based on the pavement structural and hydraulic requirements. Shall be double-washed and clean and free of all fines.
Underdrain	Use 4- to 6-inch diameter perforated HDPE or PVC (AASHTO M 252) pipe, with 3/8-inch perforations at 6 inches on center; each underdrain installed at a minimum 0.5% slope located 20 feet or less from the next pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications). Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. T's and Y's installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.	
Either Filter Layer or (See Filter Fabric below below)	The underlying native soils shall be separated from the stone reservoir by a thin, 2- to 4-inch layer of choker stone (e.g. No. 8) covered by a 6- to 8-inch layer of coarse sand (e.g. ASTM C 33, 0.02-0.04 inch).	
Filter Fabric (optional)	The underlying native soils shall be separated from the stone reservoir by a thin, 2- to 4-inch layer of choker stone (e.g. No. 8) covered by a 6- to 8-inch layer of coarse sand (e.g. ASTM C 33, 0.02-0.04 inch).	The sand shall be placed between the stone reservoir and the choker stone, which shall be placed on top of the underlying native soils.
Impermeable Liner (if needed)	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd.^{2} non-woven geotextile.	
Clean Out Point	Use a perforated 4- to 6-inch vertical PVC pipe (AASHTO M 252) with a lockable cap, installed flush with surface.	

Table 4.4.3. Different Permeable Pavement Specifications

Material	Specification	Notes
Permeable Interlocking Concrete Pavers	Surface open area: 5% to 15%. Thickness: 3.125 inches for vehicles. Compressive strength: 55 Mpa (~8000 psi). Open void fill media: aggregate	Shall conform to ASTM C936 specifications. Reservoir layer required to support the structural load.
Concrete Grid Pavers	Open void content: 20% to 50%. Thickness: 3.5 inches. Compressive strength: 35 Mpa(~5000 psi). Open void fill media: aggregate, topsoil and grass, coarse sand.	Shall conform to ASTM C 1319 specifications. Reservoir layer required to support the structural load.
Plastic Reinforced Grid Pavers	Void content: depends on fill material. Compressive strength: varies, depending on fill material. Open void fill media: aggregate, topsoil and grass, coarse sand.	Reservoir layer required to support the structural load.

4.4.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this manual. In general the following are maintenance reduction features:

Requirements DURING Construction

- Avoid undue compaction, which could affect the soils' infiltration capability.

Protection Requirements

- Provide signage for the BMP.
  - Allows for easy identification and location of the BMP.
  - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
- Design the layout of the permeable pavement such that maintenance equipment can easily achieve access.

Inspection Requirements

- Inspect the permeable pavement and underdrain for clogging or sediment buildup.
- Inspect the property that drains to the permeable pavement for erosion, exposed soil, or stockpiles of other potential pollutants.
- Use the ERIK infiltrometer at least once every 2 years

Maintenance Requirements

- Conduct mowing, weeding, and trash removal as needed to prevent obstacles to the intended drainage and maintenance of the permeable paver system. Remove grass clipping and other landscaping debris.
- Keep outlets clear of debris to prevent clogging, clear if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Prevent clogging of the aggregate through maintenance with vacuum trucks and street sweepers.
- Inspect underdrain cleanout to ensure stormwater infiltrates properly. Clean-out underdrain if necessary.

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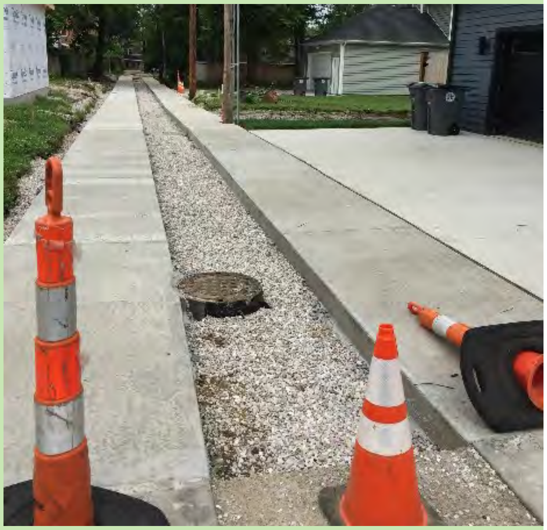
4.5 EXFILTRATION TRENCH

Figure 4.5.1. Exfiltration trenches are appropriate for retrofits, as well as new developments



DEVELOPMENT ATTRIBUTES

Construction Cost	MODERATE
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	LOW
Building Footprint Enhancement	MODERATE
Triple Bottom-Line Benefits	MODERATE

Description:
An exfiltration trench is an excavated trench consisting of a conduit such as a perforated pipe surrounded by stone aggregate used to capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench. Runoff from each rain event is captured and treated primarily through settling and filtration. The perforated pipe is used to increase the storage available in the trench and to help infiltration by evenly distributing the runoff over the length of the system.

Variations:
Constructed without underdrain in soils with measured infiltration rates greater than 0.5 inch per hour and with an underdrain in less permeable soils.

Key Advantages:

- Provides for groundwater recharge
- Good for small sites with porous soils
- Cost effective
- High community acceptance when integrated into a development

Key Limitations:

- Potential for groundwater contamination
- High clogging potential; shall not be used on sites with fine-particle soils (clays or silts) in drainage area
- Cannot be used in karst soils
- Geotechnical testing required
- Community perceived concerns with mosquitoes and safety

Performance Standard Compliance				
Water Quality				Volume and Flood Attenuation
Total Suspended Solids	Nutrients	Metals	Pathogens	
▶	▶	▶	▶	▶

▶ High ✓ Medium ✗ Low

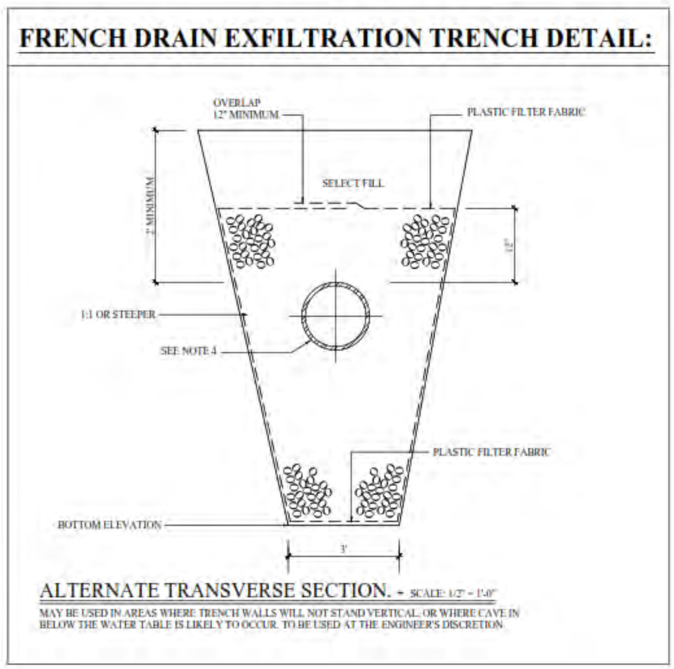
4.5.1 General Application

Exfiltration trenches are excavations typically filled with stone and a conduit to create an underground reservoir for storm water runoff. The runoff volume gradually passes through the perforated pipe and infiltrates through the bottom and sides of the trench into the subsoil over a 2-day period and eventually reaches the water table. By diverting runoff into the soil, an exfiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve base flow. Due to this fact, exfiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench.

Due to the relatively narrow shape, exfiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations, but they shall be carefully sited to avoid the potential of groundwater contamination. They are generally suited for medium-to-high density residential, commercial, and institutional developments. To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities shall not be infiltrated. Adequate geotechnical testing by qualified individuals shall be conducted to check for potential contamination issues.

Using the natural filtering properties of soil, exfiltration trenches can remove a wide variety of pollutants from storm water through sorption, precipitation, filtering, and bacterial and chemical degradation. Due to their high potential for failure, infiltration trenches shall only be considered for sites where upstream sediment control can be ensured. Exfiltration trenches are not intended to trap sediment and shall always be designed with a sediment forebay and grass channel or filter strip or other appropriate pre-treatment measures to prevent clogging and failure. The subsoil shall be sufficiently permeable to provide a reasonable infiltration rate and the water table is low enough to prevent groundwater contamination. Exfiltration trenches are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/silt soils) in the runoff and shall only be considered for sites where the sediment load is relatively low. Exfiltration trenches can either be used to capture sheet flow from a drainage area or function as an off-line device.

Figure 4.5.2. Exfiltration trench cross section



4.5.2 Planning and Physical Feasibility

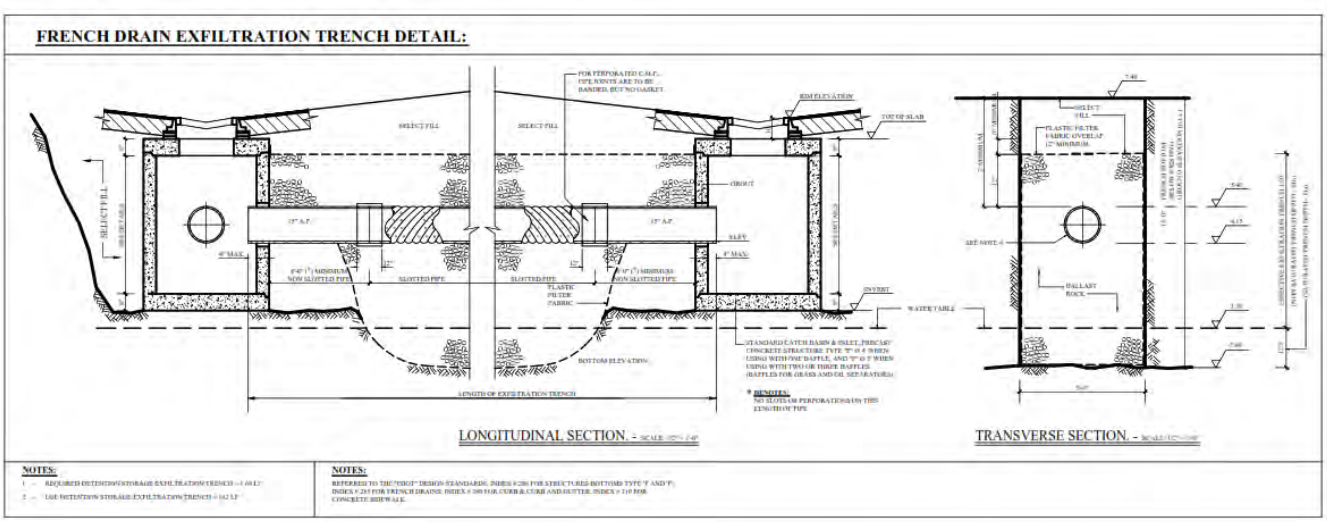
Exfiltration trenches can only be applied where there is adequate subsoil infiltration and where the risk of groundwater contamination is low. The following criteria provided in **Table 4.5.1** shall be considered when evaluating the suitability of an infiltration trench for a development site.

Table 4.5.1. Exfiltration Trench Constraints

Contributing Drainage Area	Flow-Splitter	High Loading Situations	Hotspot Land Uses	Irrigation or Baseflow
5 acres max.	Off-line configuration allows flows greater than T_v to be diverted to other BMPs with flow splitter.	Not intended to treat sites with high sediment or trash/debris loads.	Generally not allowed.	Continuous flow from groundwater, sump pumps, or other sources not permitted.
Water Table Requirement	Restrictive Layers	Setbacks	Soils Requirement	Location
2’ of separation	Clay lenses, bedrock, or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated.	Private wells require 100’. Public wells require 1,200’. Septic systems require 100’. Property lines require 10’. Building foundations require 25’. Surface waters require 100’. Surface drinking water sources require 400’ (100’ for a tributary).	0.5” per hour infiltration rate, clay content <20%, silt/clay content <40% required. Infiltration test required.	Locate in an open or lawn area, with the top of the structure close to the ground. Not permitted under pavement.

The data listed below is necessary for the design of an exfiltration trench and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing of native soils at proposed elevation of bottom of infiltration trench area.



4.5.3 Design Requirements

The major design goal for exfiltration trenches is to maximize runoff volume reduction and pollutant removal. Design criteria for exfiltration trenches are summarized in **Table 4.5.2**.

Table 4.5.2. Exfiltration Trench Design Criteria

Design Criteria
Must have the capacity to retain the required treatment volume without a discharge and without considering soil storage.
Min. of a perforated or slotted pipe diameter shall be 12”
Pipe shall not exceed 45° bends
Min. aggregate reservoir trench width shall be 3’
Aggregate void space values shall be greater than: 35% of aggregate volume; or 80% of the measured testing lab values for the selected aggregates, if obtained and certified by a Florida licensed geotechnical professional
Material used in the aggregate reservoir should have no more than 5% of the materials passing a #200 sieve
Soil infiltration rate > 0.5 in/hr
Minimum of 2 feet between the bottom of the infiltration practice to the seasonal high water tabletable or bedrock.
T_v infiltrates within 24-72 hours
Sufficient access for inspection
Min. 24” deep maintenance sump required for all system inlets and manholes Min. 12” diameter weep hole shall be placed in the bottom of the maintenance sump
Minimum setbacks – see setbacks **(Table 4.5.1)**
All Designs are subject to hotspot runoff restrictions/prohibitions

A well-designed exfiltration trench consists of:

- Excavated shallow trench backfilled with sand, coarse stone, and pea gravel and lined with a filter fabric;
- Appropriate pre-treatment measures; and
- One or more cleanout point to show how quickly the trench dewaters or to determine if the device is clogged.

Pre-Treatment

Pre-treatment of runoff entering exfiltration trenches is necessary to trap coarse sediment particles before they cause clogging. Several pre-treatment measures are feasible, depending on the scale of the infiltration practice and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flows. A low-flow diversion or flow splitter can be used at the inlet to allow only the Treatment Volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. The following are appropriate pre-treatment options:

- For a trench receiving sheet flow from an adjacent drainage area, the pre-treatment system shall consist of a vegetated filter strip with a minimum 25-foot length. A vegetated buffer strip around the entire trench is required if the facility is receiving runoff from both directions. If the infiltration rate for the underlying soils is greater than 2 inches per hour, 50% of the Tv shall be pre-treated by another method prior to reaching the infiltration trench.

- For an off-line configuration, pre-treatment shall consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber (with energy dissipaters) sized to 25% of the storage volume (Tv). Exit velocities from the pre-treatment chamber shall be nonerosive for the 2-year design storm.
- Every infiltration practice shall include multiple pre-treatment techniques, although the nature of pre-treatment practices depends on the scale at which infiltration is applied. The number, volume, and type of acceptable pre-treatment techniques needed for the two scales of infiltration are provided in **Table 4.5.3.**

Table 4.5.3. Required Pre-treatment Elements for Exfiltration Practices

Pre-treatment[1]	Scale of Exfiltration	
	Small-Scale Exfiltration	Conventional Exfiltration
Number and Volume of Pre-treatment Techniques Employed	2 techniques; 15% minimum pre-treatment volume required (inclusive).	3 techniques; 25% minimum pre-treatment volume required (inclusive); at least one separate pre-treatment cell.
Acceptable Pre-treatment Techniques	Grass filter strip, Grass channel, Plunge pool, Gravel diaphragm	Sediment trap cell, Sand filter cell, Sump pit, Grass filter strip, Gravel diaphragm

Exfiltration Trench Material Specifications

Exfiltration trenches shall have the following physical specifications/geometry:

- The required storage volume in the gravel trench is equal to the water quality volume (Tv).
- A trench shall be designed to fully dewater the entire Tv within 24 to 72 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site shall be used in the design calculations.
- Trench depths shall be between 3 and 8 feet to provide for easier maintenance. The width of a trench shall be less than 25 feet.
- Broader, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
- The bottom slope of a trench shall be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.
- The stone aggregate used in the trench shall be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 shall be used in calculations unless aggregate specific data exist.
- A 6-inch layer of clean, washed sand is placed on the bottom of the trench to encourage drainage and prevent compaction of the native soil while the stone aggregate is added.
- The exfiltration trench is lined on the sides and top by an appropriate geotextile filter fabric that prevents soil piping but has greater permeability than the parent soil. The top layer of filter fabric is located 2 to 6 inches from the top of the trench and serves to prevent sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more

frequently and shall be readily separated from the side sections.

- The top surface of the exfiltration trench above the filter fabric is typically covered with pea gravel. The pea gravel layer improves sediment filtering and maximizes the pollutant removal in the top of the trench. In addition, it can easily be removed and replaced shall the device begin to clog. Alternatively, the trench can be covered with permeable topsoil and planted with grass in a landscaped area.
- The trench excavation shall be limited to the width and depth specified in the design. Excavated material shall be placed away from the open trench so as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction and shall be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All exfiltration trench facilities shall be protected during site construction and shall be constructed after upstream areas have been stabilized.

Other design criteria for infiltration trenches include the following:

- **Outlet Structures**. Outlet structures are not required for exfiltration trenches.
- **Emergency Spillway**. Typically for off-line designs, there is no need for an emergency spillway. However, a nonerosive overflow channel shall be provided to safely pass flows that exceed the storage capacity of the trench to a stabilized downstream area or watercourse.
- **Maintenance Access**. Adequate access in an easement shall be provided to an exfiltration trench facility for inspection and maintenance.
- **Safety Features**. In general, exfiltration trenches are not likely to pose a physical threat to the public and do not need to be fenced.
- **Landscaping**. Vegetated filter strips and buffers shall fit into and blend with surrounding area. Native grasses are preferable, if compatible. The trench may be covered with permeable topsoil and planted with grass in a landscaped area.
- **Additional Site-Specific Design Criteria and Issues**. Not suitable for karst areas without adequate geotechnical testing.
- **Additional Permitting Requirements**. A Class V Injection Well Permit (UIC) may be required from FDEP.

4.5.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection and maintenance requirements, see **Appendix B** of this manual.

Requirements DURING Construction

- Construction equipment shall be restricted from the infiltration area to prevent compaction of the native soils.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over the contributing pervious drainage areas before storm water can be accepted into the infiltration trench. This will prevent sediment from clogging the infiltration area.
- Areas where BMPs will be located shall be readily identifiable and protected from unwanted encroachments during construction, both on development plans and at the construction site. Physical protection measures can include, but are not limited to, orange fencing, wood or chain link fencing, and signage. For infiltration-based practices, protection of BMP locations during construction of a land development will ensure that native soils that surround (or are within) the storm water treatment area will remain un-compacted and, therefore, continue to meet the design parameters that were specified in the approved development plan. For other practices, such as extended detention ponds, protection of BMP locations can reduce the soil compaction that typically occurs during construction, which often leads to poor soil conditions for plant growth once the BMP shall be permanently stabilized. Regardless, a lack of BMP protection will most certainly reduce or destroy the storm water functionality of the BMP once it is installed, often leading to costly corrective actions required by the Town.

Protection Requirements

- Provide signage for the BMP.
  - Allows for easy identification and location of the BMP.
  - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
  - Consider using natural fencing such as graduated vegetation sizes and densities, dense shrub fencing, rocks, or other landscape features placed in a manner that discourages foot, equipment, and vehicle traffic in the storm water treatment area.
- Design the layout of the infiltration area such that maintenance access can be achieved without the need for vehicles or equipment in the storm water treatment area.
- Provide clearly marked, easily accessible and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the storm water treatment areas.

Inspection Requirements

- Inspect the areas where storm water flows into or out of the infiltration trench for clogging or sediment buildup.
- Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.

- Inspect the property that drains to the infiltration trench for erosion, exposed soil, or stockpiles of other potential pollutants.

Maintenance Requirements

- Perform weeding, pruning, and trash removal as needed to maintain appearance.
- Inspect vegetation to evaluate health, replace if necessary.
- Keep inlets clear of debris to prevent clogging, clear if necessary.
- Inspect infiltration area for sediment build up, erosion, vegetative health/conditions, etc. perform appropriate maintenance as necessary.
- Inspect cleanout points. Clean or replace clogged aggregate if necessary.

References

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CWP. 2007. *National Pollutant Removal Performance Database, Version 3.0*. Center for Watershed Protection, Ellicott City, MD.

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Federal Highway Administration (FHWA), United States Department of Transportation. Storm water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm.

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4.6 RAINWATER HARVESTING

Figure 4.6.1. Cisterns can be blended into the overall site aesthetic

DEVELOPMENT ATTRIBUTES

Construction Cost	LOW
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	HIGH
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	MODERATE

Description:
Rain barrels and cisterns are used to intercept, divert, store, and release rain falling on rooftops for future use.

Variations:

- Aboveground Storage
- Underground Storage
- Small Residential Systems with Rain Barrels
- Large Residential or Commercial Systems with Cisterns
- Residential or Commercial Systems with Cisterns that Supply Potable Water

Key Advantages:

- Water source for non-potable uses (toilet flushing, irrigation)
- Flexible to site conditions
- Aboveground cisterns relatively easy to install and maintain
- Reduces stormwater runoff volume and peak discharge rate through retention
- Reduces pollutant loads

Key Limitations:

- Systems shall drain between storm events
- Water source for non-potable uses only
- Freight charges can be costly for large cistern purchases
- Reduction in runoff volume and peak discharge dependent on amount of storage available
- Must be childproof and sealed against mosquitos

Performance Standard Compliance				
Water Quality				Volume and Flood Attenuation
Total Suspended Solids	Nutrients	Metals	Pathogens	
✕	✕	✕	✕	✓

▶ High ✓ Medium ✕ Low

4.6.1 General Application

A cistern intercepts, diverts, stores, and releases rainfall for future use. The term cistern is used in this specification, but it is also known as a rainwater harvesting system (RHS). Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g., car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), supply for chilled water-cooling towers, and replenishing and operation of laundry, if approved by the Town.

Figure 4.6.2. Example of rain chain flowing into a Cistern

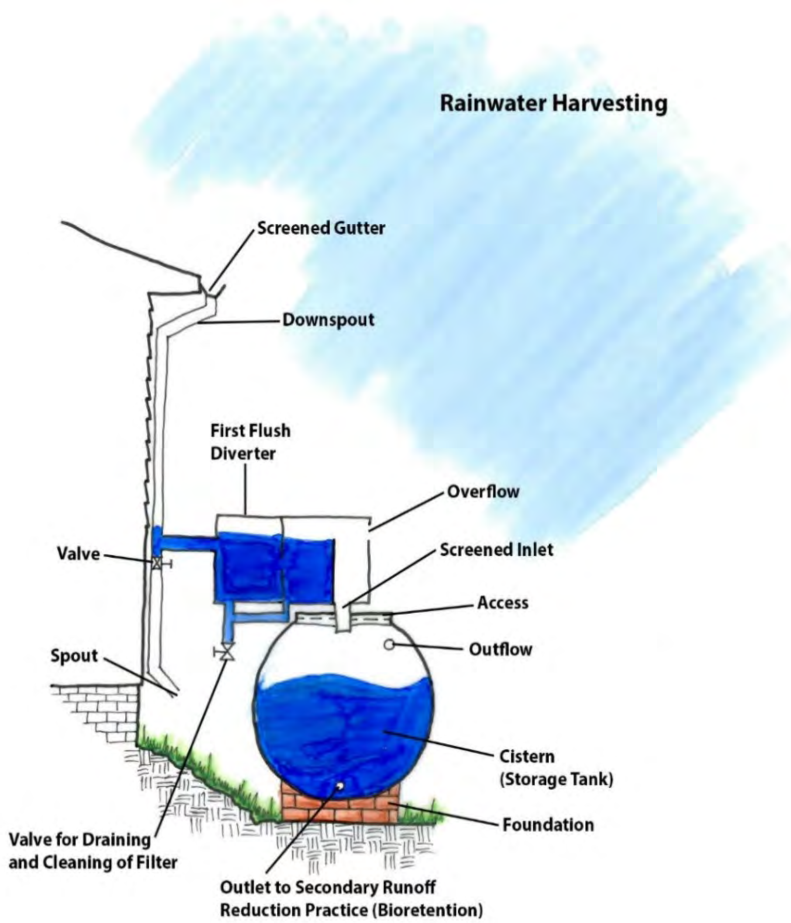
Overall, there are four types of rainwater harvesting systems: small residential systems that use rain barrels for extra irrigation; large residential or commercial systems that store rainwater in a cistern for non-potable uses; large residential or commercial systems that use a cistern as a source of indoor graywater; and residential or commercial systems that use rainwater from a cistern as potable water.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system.

Some candidate secondary practices include:

- Shallow Bioretention (**Section 4.1)**
- Rain Gardens (**Section 4.2**)
- Water Quality Swale/Enhanced Swale (**Section 4.3**)
- Exfiltration Trenches (**Section 4.5**)
- Green Roofs (**Section 4.7**)

In addition, the actual runoff reduction rates for rainwater harvesting systems are "user defined" based on tank size, configuration, demand drawdown, and use of secondary practices.



Additional considerations for use of cisterns on a development site include the following:

Roof Surface

The rooftop shall be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system.

Collection and Conveyance System

- Gutters and downspouts shall be designed as they would for a building without a rainwater harvesting system.
- Gutters shall be sized with slopes specified to contain the necessary amount of stormwater for treatment volume credit.
- Pipes (connecting downspouts to the cistern tank) shall be at a minimum slope of 1.5% and sized/designed to convey the intended design storm.

Pre-Screening and First Flush Diverter

- Inflow shall be pre-screened to remove leaves, sediment, and other debris.
- For large systems, the first flush (the first gallon of runoff per 100 square feet of roof area) of rooftop runoff shall be diverted to a secondary treatment practice to prevent sediment from entering the system.
- Rooftop runoff shall be filtered to remove sediment before it is stored.

Storage Tank

Storage tanks are sized based on consideration of indoor and outdoor water demand, long-term rainfall, and rooftop capture area.

Distribution System

- The rainwater harvesting system shall be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses.
- Distribution lines shall be installed with shutoff valves and cleanouts and shall be buried beneath the frost line or insulated to prevent freezing.

Overflow

- The system shall be designed with an overflow mechanism to divert runoff when the storage tanks are full.
- Overflows shall discharge to pervious areas set back from buildings and paved surfaces or to secondary BMPs.
- Must be sized to accommodate the 100-year/24-hour design storm flows.

4.6.2 Planning and Physical Feasibility

Several site-specific features influence how cisterns are designed and/or utilized. These should not be considered comprehensive, and the planning process shall incorporate rainwater harvesting systems into the site design. The following criteria provided in **Table 4.6.1** shall be considered when evaluating the suitability of a cistern for a development site.

Table 4.6.1. Cistern Constraints

Available Space	Building Rooftops	Rainwater Quality	Hotspot Land Uses	Hydraulic Head Needed	Contributing Drainage Area
Adequate space is needed to house the tank and any overflow. Cisterns can be underground, indoors, on rooftops or within buildings that are structurally designed to support the added weight, and adjacent to buildings.	Not permitted where roof material contains asbestos/trace metals/toxic compounds (asphalt sealcoats, tar and gravel, painted roofs, galvanized metal roofs, sheet metal). Sealant or paint roof surface shall be certified for rainwater harvesting by the National Sanitation Foundation (ANSI/NSF standard).	Low rainwater pH may result in rooftop, tank lining, or water lateral metal leaching. Limestone or other materials may need to be added in the tank to buffer acidity.	Effective BMP to prevent roof runoff from contacting ground-level hotspots. Not allowed for industrial rooftops designated as hotspots.	Cistern shall be up-gradient of intended use or use a pump.	Rooftop drainage only. Use sizing guidelines in this design specification.

Setbacks	Soils Requirement	Topography	Water Table Requirement	Utility Requirement
Building foundations require 10 feet for cistern itself and areas that will be saturated by overflows. Not permitted in areas with vehicle traffic or vehicle loads. Cisterns shall be watertight.	Sufficient bearing capacity of native soil or aggregate/concrete base required. Geotechnical test required.	Requires sufficient drop from downspout leaders to the final mechanism receiving gravity-fed discharge and/or overflow.	Sufficient fasteners/weights to prevent buoyancy. Refer to manufacturer's specifications.	Consider clearance for all utilities.

The data listed below is necessary for the design of a cistern and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Existing and proposed site, topographic and location maps, and field reviews.
- Impervious and pervious areas. Other means may be used to determine the land use data.
- Roadway and drainage profiles, cross sections, utility plans, and soil report for the site.
- Design data from nearby storm sewer structures.
- Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater.
- Infiltration testing and geotechnical testing of native soils at proposed elevation of bottom of cistern.

Stormwater Uses

The capture and reuse of rainwater can significantly reduce stormwater runoff volumes and pollutant loads. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also have environmental and economic benefits beyond stormwater management (e.g., increased water conservation, water supply during drought and mandatory municipal water supply restrictions, decreased demand on municipal or groundwater supply, decreased water costs for the end-user, potential for increased groundwater recharge, etc). To enhance their runoff reduction and nutrient removal capability, rainwater harvesting systems can be combined with other rooftop disconnection practices, such as shallow bioretention (**Section 4.1**) and rain gardens (**Section 4.2**). In this specification, these allied practices are referred to as “secondary runoff reduction practices.” While the most common uses of captured rainwater are for non-potable purposes, such as those noted above, in some limited cases rainwater can be treated to potable standards. This is permitted within Cutler Bay at this time.

4.6.3 Design Objectives and System Configurations

Many rainwater harvesting system variations can be designed to meet user demand and stormwater objectives. There are numerous potential configurations that could be implemented, yet the main four types of rainwater harvesting systems are explained below.

Type 1: Non-potable Residential System with a Rain Barrel (Figure 4.6.3). The first type of system is used in a residential setting where rainwater is stored in a rain barrel. These systems allow owners to retrofit their homes in order to reduce runoff and the amount of potable water consumed for irrigation. There are many different sources on designing and installing these systems available on the internet and at home centers. Cutler Bay encourages the use of rain barrels by homeowners; however, they do not qualify for stormwater credit.

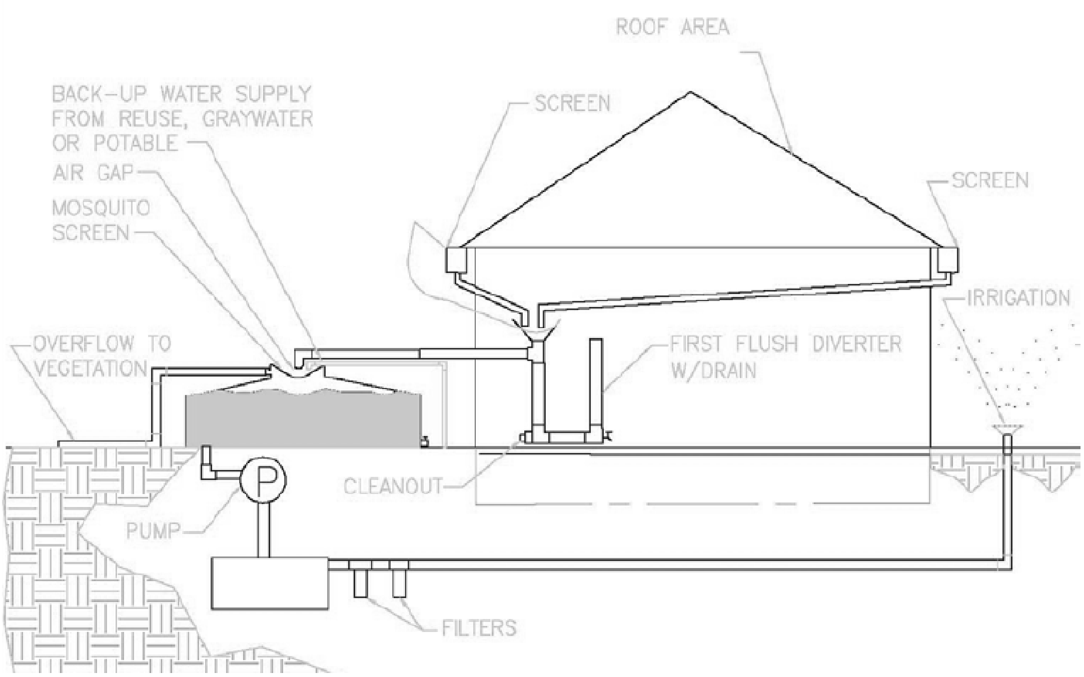
Figure 4.6.3: Type 1: Rainwater Harvesting with a Rain Barrel

Source: Sarasota County LID Guidance Document

Type 2: Non-potable System for outdoor Use with a Cistern (Figure 4.6.4). The next type of system is a large commercial or residential system that uses a cistern to store water for irrigation and/or other outdoor uses. In these systems:

- Rainwater is collected by gutters and scuppers and routed through downspouts to a cistern.
- The downspouts are equipped with a device to divert the first flush of water away from the cistern and to screen out large material such as leaves.
- Cisterns are larger than 80 gallons and may provide aboveground or underground storage. If the cistern is underground, it must be constrained against buoyant forces.
- The irrigation system will likely require additional filtration and screening to prevent valves and spray heads from clogging.
- The harvested rainwater may require a piping system to distribute the water to its final destination.
- The components for this type of system are shown in **Figure 4.6.4**.

Figure 4.6.4: Type 2: Non-potable System for Outdoor Use with a Cistern



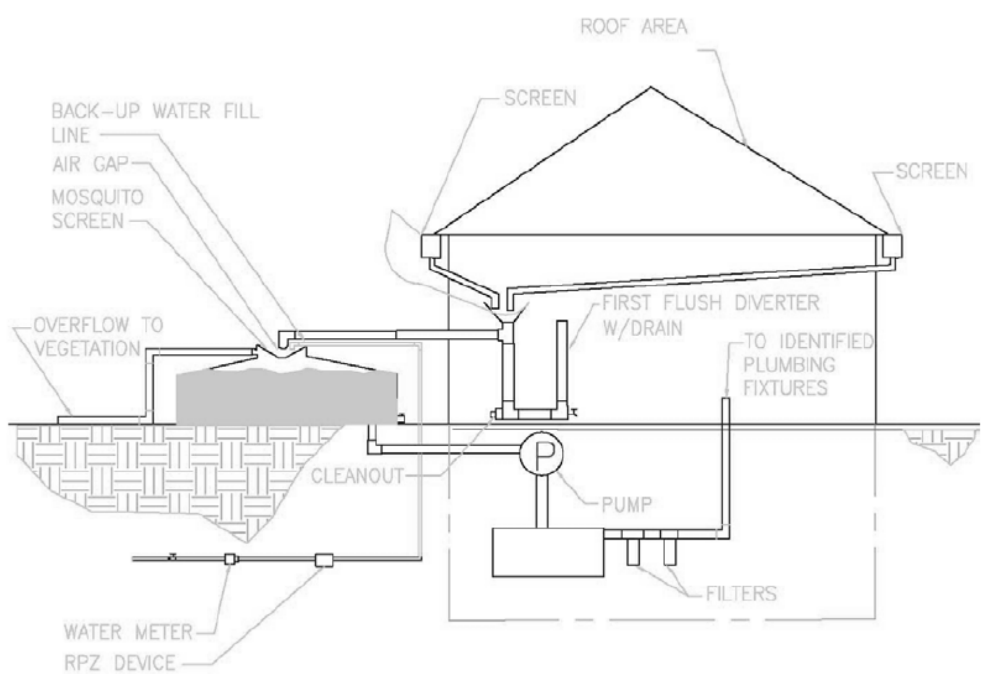
Source: LID Sarasota County

Type 3: Non-potable System for Indoor and outdoor Use with a Cistern (Figure 4.6.5). The third type of system is a large residential or commercial system that stores rainwater in a cistern for indoor uses such as toilet flushing, urinal flushing, HVAC make-up water, exterior washing, laundry wash water, and other outdoor uses. In these systems:

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

This type of system has a potential for inadvertent human contact or consumption; therefore, the system has additional requirements from the Cutler Bay Health Department.

Figure 4.6.5: Type 3: Non-potable System for Indoor and Outdoor Use with a Cistern



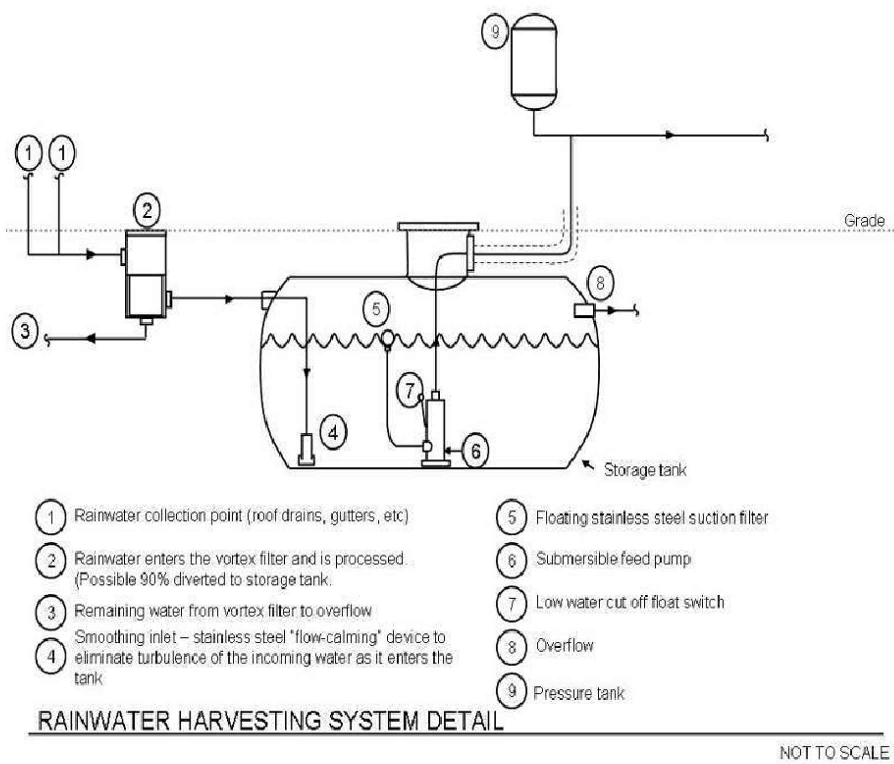
Source: LID Sarasota County

Type 4: Potable Use with a Cistern (Figure 4.6.6). The fourth type of system is a residential or commercial system that stores rainwater in a cistern as a source of potable water. This type of system is designed for human consumption. Therefore, the system has additional design, operation, and permitting requirements from the local and state regulations.

System Components
There are six primary components of a rainwater harvesting system (**Figure 4.6.6**):

- Roof surface
- Collection and conveyance system (e.g. gutter and downspouts)
- Pre-screening and first flush diverter
- Storage tank
- Distribution system
- Overflow, filter path, or secondary runoff reduction practice

Figure 4.6.6: Sample Rainwater Harvesting System Detail



Source: VADCR, 2011

Each of these system components is discussed below:

- **Rooftop Surface.** The rooftop shall be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater is selected for uses with significant human exposure (e.g., pool filling, watering vegetable gardens), care shall be taken in the choice of roof materials. Some materials may leach toxic chemicals making the water unsafe for humans.

- **Collection and Conveyance System.** The collection and conveyance system consist of the gutters, downspouts, and pipes that channel stormwater runoff into storage tanks. Gutters and downspouts shall be designed as they would for a building without a rainwater harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for rainwater harvesting. Minimum slopes of gutters shall be specified. At a minimum, gutters shall be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour for treatment volume credit. If volume credit will also be sought for channel and flood protection, the gutters shall be designed to convey the 2 and 10-year storm, using the appropriate 2- and 10-year storm intensities, specifying size and minimum slope. In all cases, gutters shall be hung at a minimum of 0.5% for 2/3 of the length and at 1% for the remaining 1/3 of the length.

  Pipes (connecting downspouts to the cistern tank) shall be at a minimum slope of 1.5% and sized/designed to convey the intended design storm, as specified above. In some cases, a steeper slope and larger sizes may be recommended and/or necessary to convey the required runoff, depending on the design objective and design storm intensity. Gutters and downspouts shall be kept clean and free of debris and rust.

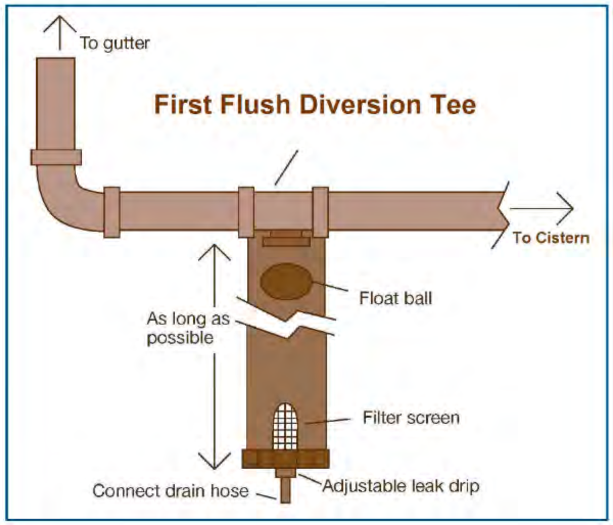
- **Pre-Treatment: Screening, First Flush Diverters and Filter Efficiencies.** Pre-filtration is required to keep sediment, leaves, contaminants, and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-filtration of small systems, although direct water filtration is preferred. All pre-filtration devices shall be low-maintenance or maintenance-free. The purpose of pre-filtration is to significantly cut down on maintenance by preventing organic buildup in the tank, thereby decreasing microbial food sources. Indoor graywater systems require pre-filtering and fine filtering to between 5 and 20 microns.

  For larger tank systems, the initial first flush shall be diverted from the system before rainwater enters the storage tank. Designers should note that the term “first flush” in rainwater harvesting design does not have the same meaning as has been applied historically in the design of stormwater treatment practices. In this specification, the term “first flush diversion” is used to distinguish it from the traditional stormwater management term “first flush”. This amount should be approximately the first gallon of runoff per 100 square feet of roof area.

  The diverted flows (first flush diversion and overflow from the filter) shall be directed to an acceptable pervious flow path that will not cause erosion during a 2-year storm or to an appropriate BMP on the property for infiltration. Preferably the diversion will be conveyed to the same secondary runoff reduction practice that is used to receive tank overflows.

Various first flush diverters are described below. In addition to the initial first flush diversion, filters have an associated efficiency curve that estimates the percentage of rooftop runoff that will be conveyed through the filter to the storage tank. If filters are not sized properly, a large portion of the rooftop runoff may be diverted and not conveyed to the tank at all. A design intensity of 1 inch/hour shall be used for the purposes of sizing pre-tank conveyance and filter components. This design intensity captures a significant portion of the total rainfall during a large majority of rainfall events (NOAA 2004). If the system will be used for channel and flood protection, the 2- and 10-year storm intensities shall be used for the design of the conveyance and pre-treatment portion of the system. For the 1-inch storm treatment volume, a minimum of 95% filter efficiency is required. This efficiency includes the first flush diversion. For the 2- and 10-year storms, a minimum filter efficiency of 90% shall be met.

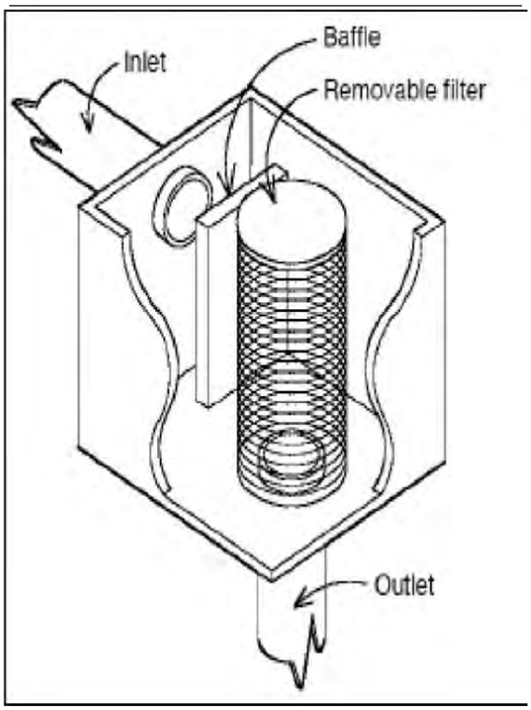
Figure 4.6.7: First Flush Diverter



Source: LID Sarasota Manual

- **First Flush Diverters.** First flush diverters direct the initial pulse of stormwater runoff away from the storage tank. While leaf screens effectively remove larger debris such as leaves, twigs, and blooms from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen, and bird and rodent feces (**Figure 4.6.7**). Simple first flush diverters require active management by draining the first flush water volume to a pervious area following each rainstorm. First flush diverters may be the preferred pre-treatment method if the water is to be used for indoor purposes. A vortex filter may serve as an effective pre-tank filtration device and first flush diverter.

Figure 4.6.8: Roof Washer



Source: VADCR, 2011

- **Leaf Screens.** Leaf screens are mesh screens installed over either the gutter or downspout to separate leaves and other large debris from rooftop runoff. Leaf screens shall be regularly cleaned to be effective; if not maintained, they can become clogged and prevent rainwater from flowing into the storage tanks. Built-up debris can also harbor bacterial growth within gutters or downspouts (TWDB, 2005).

- **Roof Washers.** Roof washers are placed just ahead of storage tanks and are used to filter small debris from harvested rainwater (**Figure 4.6.8**). Roof washers consist of a tank, usually between 25 and 50 gallons in size, with leaf strainers and a filter with openings as small as 30-microns (TWDB, 2005). The filter functions to remove very small particulate matter from harvested rainwater. All roof washers shall be cleaned on a regular basis.

- **Vortex Filters.** For large scale applications, vortex filters can provide filtering of rooftop rainwater from larger rooftop areas. **Figure 4.6.9** provides a plan view photograph showing the interior of the filter with the top off and the filter just installed in the field prior to the backfill.

Figure 4.6.9. Interior of Vortex (left) and Installation of Vortex Filter Prior to Backfill (right)

Source: VADCR, 2011

Storage Tanks. The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities range from 250 to over 30,000 gallons. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and increase overall storage on-site as needed. Typical rainwater harvesting system capacities for residential use range from 1,500 to 5,000 gallons. The installation must follow the Florida Building Code for Plumbing and the Florida Building Code for Electrical.

While many of the graphics and photos in this specification depict cisterns with a cylindrical shape, the tanks can be made of many materials and configured in various shapes, depending on the type used and the site conditions where the tanks will be installed. For example, configurations can be rectangular, L-shaped, or step vertically to match the topography of a site. The following factors shall be considered when designing a rainwater harvesting system and selecting a storage tank:

- Aboveground storage tanks shall be UV and impact resistant.
- Underground storage tanks shall be designed to support the overlying sediment and any other anticipated loads (e.g., vehicles, pedestrian traffic, etc.).
- Underground rainwater harvesting systems shall have a standard size manhole or equivalent opening to allow access for cleaning, inspection, and maintenance purposes. This access point shall be secured/locked to prevent unwanted access.
- All rainwater harvesting systems shall be sealed using a water-safe, non-toxic substance.
- Rainwater harvesting systems may be ordered from a manufacturer or can be constructed on site from a variety of materials. **Table 4.6.2** below compares the advantages and disadvantages of different storage tank materials.
- Storage tanks shall be opaque or otherwise protected from direct sunlight to inhibit algae growth and shall be screened to discourage mosquito breeding and reproduction.

- Dead storage below the outlet to the distribution system and an air gap at the top of the tank shall be added to the total volume. For gravity-fed systems, a minimum of 6 inches of dead storage shall be provided. For systems using a pump, the dead storage depth will be based on the pump specifications.
- Any hookup to a municipal backup water supply shall have a backflow prevention device to keep municipal water separate from stored rainwater. Check with the local and state guidance for any regulations pertaining to this.

Table 4.6.2. Advantages and Disadvantages of Various Cistern Materials

Tank Material	Advantages	Disadvantages
Fiberglass	Commercially available, alterable, and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application	Shall be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application	Can beUV-degradable; shall be painted or tinted for above-ground installations; pressure-proof for below- ground installation
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive	Longevity may be less than other materials; higher risk of puncturing of water tight membrane during construction
Plastic Barrels	Commercially available; inexpensive	Low storage capacity (20 to 50 gallons); limited application
Galvanized Steel	Commercially available, alterable, and moveable; available in a range of sizes; film develops inside to prevent corrosion	Possible external corrosion and rust; shall be lined for potable use; can only install above ground; soil pH may limit underground applications
Steel Drums	Commercially available, alterable, and moveable	Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications
FerroConcrete	Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; expensive
Cast in Place Concrete	Durable, immoveable, versatile; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils
Stone or Concrete Block	Durable and immoveable; keeps water cool in summer months	Difficult to maintain; expensive to build

Source: Cabell Brand (2007, 2009)

Rainwater Harvesting Material Specifications

The basic material specifications for rainwater harvesting systems are presented in **Table 4.6.3**. Designers shall consult with experienced rainwater harvesting system and irrigation installers on the choice of recommended manufacturers of prefabricated tanks and other system components.

Table 4.6.3. Design Specifications for Cisterns

Item	Specification
Gutters and Downspout	Materials commonly used for gutters and downspouts include PVC pipe, vinyl, aluminum, and galvanized steel. Lead shall not be used as gutter and downspout solder since rainwater can dissolve the lead and contaminate the water supply. • The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks. • Be sure to include needed bends and tees.
Pre-Treatment	At least one of the following (all rainwater to pass through pre-treatment): • First flush diverter • Vortex filter • Roof washer • Leaf and mosquito screen (1 mm mesh size)
Storage Tanks	• Materials used to construct storage tanks shall be structurally sound. • Tanks shall be constructed in areas of the site where native soils can support the load associated with stored water. • Storage tanks shall be water tight and sealed using a water-safe, non-toxic substance. • Tanks shall be opaque to prevent the growth of algae. • Re-used tanks shall be fit for potable water or food-grade products. • Underground rainwater harvesting systems shall have a minimum of 18 to 24 inches of soil cover and be located below the frost line. • The size of the rainwater harvesting system(s) is determined during the design calculations.

Note: This table does not address indoor systems or pumps.

4.6.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this manual.

Requirements DURING Construction

- Appropriate containment shall be used for material storage to prevent accidental discharge to the cistern.
- A dense and vigorous vegetative cover, or other effective soil stabilization practice, shall be established over area receiving overflow runoff before stormwater can be accepted into the cistern. This will prevent erosion down-gradient of the cistern.

Protection Requirements

- Provide signage for the BMP.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.
- Design the layout of the BMP such that maintenance access can be achieved without the need for vehicles or equipment in the stormwater treatment area.
- Provide clearly marked, easily accessible, and well-maintained driveways, sidewalks, and pedestrian pathways that lead vehicles, equipment, and foot traffic around the stormwater treatment areas.

Inspection Requirements

- Inspect for damaged cistern and rooftop components.
- Inspect the property that receives water and overflow for signs of erosion.

Maintenance Requirements

- Inspect surrounding area for sediment build up, erosion, vegetative health/conditions, etc. Perform appropriate maintenance as necessary.
- Inspect cistern for signs of corrosion or failure and maintain as needed.
- **Record Keeping**: The owner/operator of an RHS must keep a maintenance log of activities that is available at any time for inspection or recertification purposes. The maintenance log shall include the following:
    - Rainwater volume harvested using a flow meter specifying the day, time, and volume;
    - Rainwater volume irrigated or otherwise used using a flow meter specifying the day, time, and volume used;
    - Observations of the RHS operation, maintenance, and a list of parts that were replaced;
    - Observations of the irrigation system operation, maintenance, and a list of parts that were replaced; and
    - Dates on which the RHS and irrigation (or other use systems) were inspected and maintenance activities conducted.

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4.7 GREEN ROOF

Figure 4.7.1. Greenroofs can include pathways and other amenities.

DEVELOPMENT ATTRIBUTES

Construction Cost	HIGH
Operation and Maintenance Cost	MODERATE
Ground-Level Encroachment	LOW
Building Footprint Enhancement	LOW
Triple Bottom-Line Benefits	HIGH

Description:
A green roof is a layer of vegetation installed on top of a conventional flat or slightly sloped roof. It consists of waterproofing material, root permeable filter fabric, growing media, and specially selected plants.

Variations:
- Extensive green roofs have a thin layer of growing medium and are usually composed of sedums.
- Intensive green roofs have a thicker layer of growing medium and contain shrubs, trees, and other vegetation.
- Active green roofs are typically greater than four inches in depth of growing media and allow public access; passive green roofs are shallower and do not allow access.

Key Advantages:
- Runoff volume reduction
- Provides flow attenuation
- Extends the life of a conventional roof by up to 50 years
- Provides increased insulation and energy savings
- Reduces air pollution
- Provides habitat for wildlife
- Increases aesthetic value
- Provides sound insulation
- Provides water quality treatment
- Reduces urban heat island effect

Key Limitations:
- Cost may be greater than a conventional roof, and feasibility is limited by load-bearing capacity of roof
- Must obtain necessary permits and comply with local building codes
- Requires more maintenance than a conventional roof
- May require irrigation

Performance Standard Compliance				
Water Quality				
Total Suspended Solids	Nutrients	Metals	Pathogens	Volume and Flood Attenuation
✗	✗	✗/✓	✓	✓/▶

▶ High ✓ Medium ✗ Low

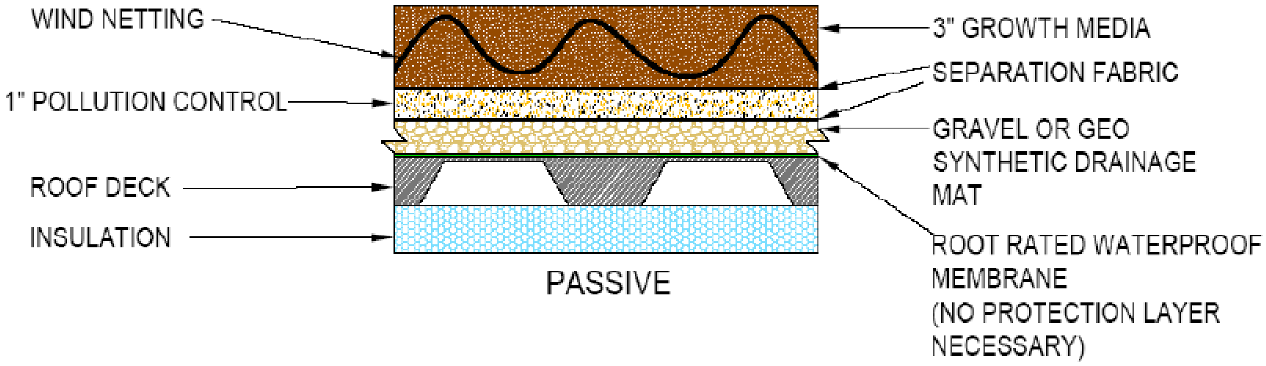
4.7.1 General Application

Figure 4.7.2. Active greenroofs are designed to allow public access.

Greenroofs (also known as green roofs, living roofs, or ecoroofs) are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Greenroofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites. The filtrate from the greenroof typically collected in a cistern or other appropriate storage container. See **Section 4.6 Rainwater Harvesting** for more information on cisterns.

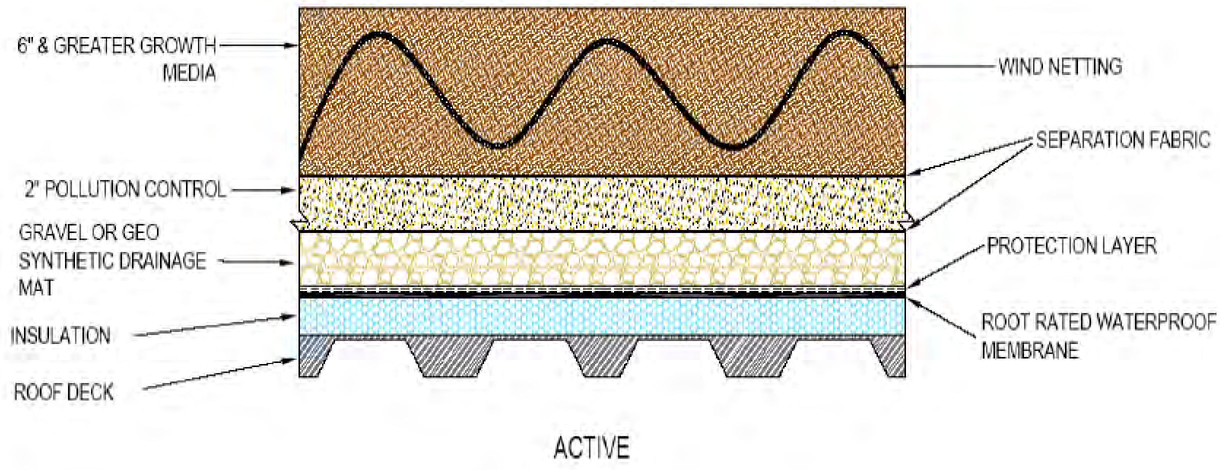
There are two different types of greenroof systems: *intensive* greenroofs and *extensive* greenroofs. Intensive systems have a deeper growing media layer that ranges from 6 inches to 4 feet thick, which is planted with a wider variety of plants, including trees. By contrast, extensive systems typically have much shallower growing media (under 6 inches), which is planted with carefully selected drought tolerant vegetation. Extensive greenroofs are much lighter and less expensive than intensive greenroofs and are recommended for use on most development and redevelopment sites. There are two distinct functions for greenroofs, one is passive and the other is active. Passive greenroofs are intended only for maintenance access and typically require less maintenance (typically an extensive system), while an active roof is used for public and private access (typically an intensive system).

Figure 4.7.2a Extensive Greenroof Section (Usually Passive Function)



Source: PC Stormwater Manual

Figure 4.7.2b Intensive Greenroof Section (Usually Active Function) (PC Stormwater Manual)

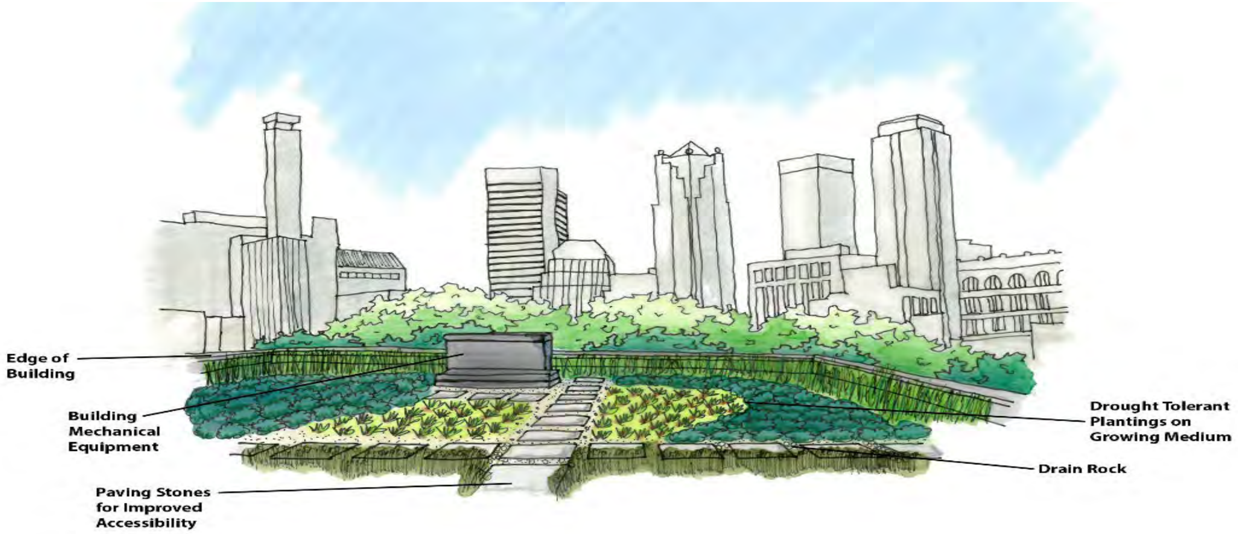


Source: PC Stormwater Manual

NOTE: This manual is intended for situations where the primary design objective of the greenroof is stormwater management and, unless specified otherwise, addresses extensive roof systems.

Designers may wish to pursue other design objectives for greenroofs, such as energy efficiency, green building or LEED points, architectural considerations, visual amenities, and landscaping features, which are often maximized with intensive greenroof systems. However, these design objectives are beyond the scope of this manual.

Greenroofs typically contain a layered system of roofing, which is designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The roofs are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet. Extensive green roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. Tray systems are also available with removable dividers allowing the media to meld together creating a seamless appearance, but with less difficulty in construction.



4.7.2 Planning and Physical Feasibility

Greenroofs are ideal for use on commercial, institutional, municipal, and multi-family residential buildings. They are particularly well suited for use on ultra-urban development and redevelopment sites. Greenroofs can be used on a variety of rooftops, including the following:

- Non-residential buildings (e.g., commercial, industrial, institutional, and transportation uses)
- Multi-family residential buildings (e.g., condominiums or apartments)
- Mixed-use buildings

The following criteria provided it **Table 4.7.1** shall be considered when evaluating the suitability of a green roof for a development site.

Table 4.7.1. Green Roof Constraints

Building Codes	Construction Cost	Structural Capacity of Roof	Risk of Roof Leaks	Retrofitting
Roof drains/emergency overflow requirements shall be met. If it is designed to be accessible, the access must adhere to Town access and safety requirements.	Can cost between $12 and $25 per square foot, but cost savings exist due to increased energy efficiency, real estate desirability, and increased roof longevity.	A structural engineer, architect, or other qualified professional shall account for additional weight of potential water in design.	Well designed and installed green roofs have less problems with leaks than traditional roofs (see Chapter 9 in Weiler and Scholz-Barth (2009)).	Area, age, accessibility, maintenance effort, and structural capacity shall be evaluated.
Roof Access	**Roof Pitch**	**Roof Type**	**Non-Vegetated Areas**	**Space Required**
Opening 16 sq. ft. in area with a min. dimension of 24 in. required. Material delivery/stockpiling shall also be considered.	1 to 2% pitch maximizes treatment volume (T_v). Steep pitch allowed (up to 25%) but reduces T_v and requires baffles/ grids/strips to prevent media slippage.	Concrete roof decks are preferred. Exposed treated wood and uncoated galvanized metal may not be appropriate.	A maximum of 20% of the non-vegetated areas (access paths/ mechanical equipment/ photovoltaic panels/skylights) counts as part of the green roof for calculation purposes.	For a cistern and pond.
Building Height	**Sun Exposure**	**Parapets**		
Will affect the plant selection.	The amount of sun exposure to the building will affect plant selection.	Designed and provided as wind protection		

The data listed below is necessary for the design of a green roof and shall be included with the Stormwater Report. See **Appendix B** for more information on required elements for the Stormwater Report.

- Architectural roof plan with rooftop pitches and downspout locations
- The proposed site design, including, buildings, parking lots, sidewalks, stairs and handicapped ramps, and landscaped areas for downspout discharge locations and bypass outfalls
- Information about downstream BMPs and receiving waters
- A planting plan prepared by a landscape architect, botanist, or other qualified professional

4.7.3 Design Considerations and Requirements

This manual includes the minimum standards for the design of a greenroof stormwater treatment system in Cutler Bay. Applicants should consult with SWFWMD and Planning and Development Services, or its successor to determine whether there are any variations of these criteria or if they must follow additional standards.

A structural engineer must certify that the roof can support the weight load of the greenroof system.

To assure that a greenroof built in Florida remains operable, the greenroof must be designed to prevent wind uplift. A three-dimensional netting made of polyamide (nylon) filaments connected together woven into the upper 1” layer of the growth media or equivalent method is acceptable. A parapet of sufficient height can be used as an alternate. For buildings less than 100 feet tall, a parapet height of 36” can be used in place of wind netting.

Peak Discharge Requirements

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

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

Figure 4.7.3. Greenroof Cross-Sections

Source: B.Hunt, NCSU

Structural Capacity of the Roof

Greenroofs can be limited by the additional weight of the fully saturated growing medium and plants in terms of the physical capacity of the roof to bear structural loads. The designer shall consult with a licensed structural engineer or architect to ensure that the building will be able to support the additional live and dead structural load and determine the maximum depth of the greenroof system and any needed structural reinforcement.

In most cases, fully-saturated extensive greenroofs have a maximum load of about 30 lbs./sq. ft., which is fairly similar to traditional new rooftops (12 to 15 lbs./sq. ft.) that have a waterproofing layer anchored with stone ballast. For an excellent discussion of greenroof structural design issues, consult Chapter 9 in Weiler and Scholz-

Barth (2009) and ASTM E2397, *Standard Practice for Determination of Dead Loads and Live Loads Associated with Green (Vegetated) Roof Systems*.

Functional Elements of a Greenroof System

A greenroof is composed of up to eight different systems or layers, from bottom to top, that are combined together to protect the roof and maintain a vigorous cover. Designers can employ a wide range of materials for each layer, which can differ in cost, performance, and structural load. The entire system as a whole shall be assessed to meet design requirements. Some manufacturers offer proprietary greenroofing systems, whereas in other cases, the designer or architect shall assemble their own system, in which case they are advised to consult Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006), and Dunnett and Kingsbury (2004)**.**

- **Deck Layer.** The roof deck layer is the foundation of a greenroof. It may be composed of concrete, wood, metal, plastic, gypsum, or a composite material. The type of deck material determines the strength, load bearing capacity, longevity, and potential need for insulation in the greenroof system. In general, concrete decks are preferred for greenroofs, although other materials can be used as long as the appropriate system components are matched to them.

Figure 4.7.4. Flood Testing the Waterproofing Layer

- **Waterproof Membrane.** All greenroof systems shall include an effective and reliable waterproofing layer to prevent water damage through the deck layer. A wide range of waterproofing materials can be used, including built up roofs, modified bitumen, single-ply, and liquid-applied methods (see Weiler and Scholz-Barth, 2009 and Snodgrass and Snodgrass, 2006). The waterproofing layer shall be 100% waterproof and have an expected life span as long as any other element of the greenroof system.

- **Insulation Layer.** Many greenroof tops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs). According to Snodgrass and Snodgrass (2006), the trend is to install insulation on the outside of the building, in part to avoid mildew problems.

- **Pollution Control (Optional).** The next layer of a greenroof system is an optional root barrier that protects the waterproofing membrane from root penetration. A wide range of root barrier options are described in Weiler and Scholz-Barth (2009). Chemical root barriers or physical root barriers that have been impregnated with pesticides, metals, or other chemicals that could leach into stormwater runoff shall be avoided.

Figure 4.7.5. Drainage Layer Installation

- **Drainage Layer and Drainage System.** A drainage layer is then placed between the optional root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer shall consist of synthetic or inorganic materials (e.g., gravel, recycled polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors, and roof leader. The required depth of the drainage layer is governed by both the required stormwater storage capacity and the structural capacity of the rooftop. ASTM E2396 and E2398 can be used to evaluate alternative material specifications.

- **Separation Fabric**. A semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it.

Figure 4.7.6. Delivery of Growing Media

Figure 4.7.7. Trays of Sedums

- **Growing Media**. The next layer in an extensive greenroof is the growing media, which is typically 4 to 6 inches deep for extensive roofs and 6 inches or more for intensive roofs. 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.
  - The media should be over 50% mineral and should contain no shale or other materials dark in color.
  - At least 3" 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.
  - If trees are included, the depth of the media should be adjusted to support the root structure of mature trees.
  - pH is between 6.5 and 8.0.
  - Soluble salts are led than 3.5 (KCL)/L.

- **Irrigation system.** Drip irrigation, which uses less water and is more easily controlled, is highly recommended. Drip irrigation should be placed as close as possible to the plants, usually with one foot on-center spacing. Irrigation water shall be supplied from a non-potable source such as a cistern or water storage area first. Backflow prevention devices on any auxiliary back-up source must be provided and requires an annual inspection. Irrigation rates vary with the season but shall be less than 1.5 inches per week. A rain shut-off sensor or soil moisture sensors is required for irrigation shut off.

- **Vegetation Layer.** The top layer of a greenroof typically consists of slow-growing, shallow-rooted, perennial, succulent plants that can withstand harsh conditions at the roof surface. An experienced design professional shall be consulted to select the plant species best suited to a given installation. A mix of base ground covers (usually Sedum species) and accent plants can be used to enhance the visual amenity value of a green roof.

  Local nurseries should be consulted for native and Florida-friendly plant recommendations. Plants must achieve at least 80% cover of the greenroof area within one year of planting. When the vegetation density is less than 80%, new plants shall be added. On passive roofs, low profile plants are preferred. There must be a plan for securing larger plants and trees, if used, against high winds. Shade from surrounding buildings and trees shall be considered in the plant selection. Low maintenance plants and drought tolerant plants are recommended but not mandatory because of the use of stored stormwater for irrigation. **Table 4.7.2** includes plants that have been successfully used on greenroofs in different parts of Florida.

Table 4.7.2. Plants that have been successfully used on greenroofs in Florida

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

Source: PC Stormwater Manual

- **Filter Media.** The recommended growing media for extensive greenroofs is composed of approximately 80% to 90% lightweight inorganic materials, such as expanded slates, shales or clays, pumice, scoria, or other similar materials. The remaining media shall contain no more than 15% organic matter, normally well-aged compost. The percentage of organic matter shall be limited, since it can leach nutrients into the runoff from the roof and clog the permeable filter fabric. The growing media shall have a maximum water retention capacity of around 30%. It is advisable to mix the media in a batch facility prior to delivery to the roof. More information on growing media can be found in Weiler and Scholz-Barth (2009) and Snodgrass and Snodgrass (2006).

  The composition of growing media for intensive greenroofs may be different, and it is often much greater in depth (e.g., 6 inches to 4 feet). If trees are included in the greenroof planting plan, the growing media shall provide enough volume for the root structure of mature trees.

- **Conveyance and Overflow.** The drainage layer below the growth media shall be designed to convey the 10-year storm without backing water up to into the growing media. The drainage layer shall convey flow to an outlet or overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the greenroof surface. Roof drains immediately adjacent to the growing media shall be boxed and protected by flashing that extends at least 3 inches above the growing media to prevent clogging. For back-up watering and emergency purposes, a water "bibb" is typically available on or near the roof line.

Greenroof Material Specifications

Standards specifications for North American greenroofs continue to evolve, and no universal material specifications exist that cover the wide range of roof types and system components currently available. The American Society for Testing and Materials (ASTM) has recently issued several overarching greenroof standards, which are described and referenced in **Table 4.7.3.** Designers and reviewers shall also fully understand manufacturer specifications for each system component, particularly if they choose to install proprietary "complete" greenroof systems or modules.

Table 4.7.3 Extensive Greenroof Material Specifications

Material	Specification
Roof	Structural Capacity shall conform to ASTM E2397-05, Practice for Determination of Live Loads and Dead Loads Associated with Green (Vegetated) Roof Systems. In addition, use standard test methods ASTM E2398-05 for Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems, and ASTM E2399-05 for Maximum Media Density for Dead Load Analysis.
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier (Optional)	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	1 to 2-inch layer of clean, washed granular material, such as ASTM D 448 size No. 8 stone. Roof drains and emergency overflow shall be designed in accordance with Metro Codes.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent.
Growth Media	85% lightweight inorganic materials and 15% organic matter (e.g. well-aged compost). Media shall have a maximum water retention capacity of around 30%. Media shall provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-05.
Plant Materials	Low plants such as sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost. See ASTM E2400-06, Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems.

4.7.4 Construction, Protection, and Maintenance Requirements

All BMPs require proper construction, protection, and long-term maintenance or they will not function as designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. A legally binding Inspection, Protection, and Maintenance agreement shall be completed. For Town policies, additional guidance and forms pertaining to BMP protection, inspection, and maintenance requirements, see **Appendix B** of this Manual.

Requirements DURING Construction

- Care shall be given to avoid damage to the waterproofing membrane during installation of the green roof. If the integrity of the membrane is compromised in a manner that may cause leaks or roof damage, the area shall be identified and repaired. Visually inspect for damage and test the membrane for water tightness prior to installation of the engineered growing media.
- If the roof is sloped, stabilization measures may be required before installing the green roof to prevent soil from sliding down the roof. Some situations may allow the stabilization measures to be incorporated into the roof structure.
- Install the green roof according to the manufacturer's instructions. Usually the root barrier layer, walkway, and irrigation system are installed first.
- To help prevent compaction of the engineered growing media, heavy foot traffic shall be kept off of green roof surfaces during and after construction.
- Construction contracts shall contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a green roof.
- The Designated Responsible Entity is required to provide for the inspection of the total stormwater management system by a Florida registered Professional Engineer to assure that the system is properly operated and maintained. The inspections must be performed 18 months after operation is authorized by both the County and District and every 18 months thereafter. The report is due within 30 days of the date of inspection and submitted to Cutler Bay Stormwater or its successor.

Protection Requirements

- Consider signage and appropriate receptacles for litter and pet waste if the green roof is accessible.
- Provide signage for the BMP.
    - Allows for easy identification and location of the BMP.
    - Serves as a general education tool, making those responsible for property, landscape or BMP maintenance, and the general public aware of the water quality features of the BMP and to avoid encroachment.

Inspection Requirements

- Access to the site is adequate for inspection and maintenance.
- Area is clean (trash, debris, grass clippings, weeds etc. removed).
- Inspect green roof for dead or dying vegetation.
- Inlet and outlet pipes are free of trash, debris, etc. Inspect for ponding that may signify clogging at inflow points.
- Inspect waterproof membrane.
- No signs of structural deficiency or settling.
- Inspect overflow devices to ensure proper operation.

Maintenance Requirements

- Dead vegetation shall be removed along with any woody vegetation.
- Plant replacement vegetation as needed.
- Remove trash, debris, and other pollutants from the rooftop.
- Remove any accumulated sediment or debris.
- The maintenance record or log of activities should include data on the following:
    - Irrigation volume measured using a flow meter.
    - Cistern overflow volume.
    - Observations of the irrigation system and replacement of parts.
    - Removal of nuisance species or invasive exotics.
    - Removal and replacement of dead, dying, or damaged plants. Use different plant species in the location if the problem persists.
    - Maintenance if roof mechanical equipment.
    - Fertilizer, pesticides, and compost added consistent with ground-surface-level use.

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Weiler, S. and K. Scholz-Barth 2009. Green Roof Systems: A Guide to the Planning, Design, and Construction of Landscapes over Structure. Wiley Press. New York, NY.

5 Appendices

Appendix A: Examples of Florida Municipalities and LID Projects

Appendix B: Development Checklists

APPENDIX A: FLORIDA MUNICIPALITIES AND LID PROJECTS

Table A.1. Summary of several Florida LID Manuals

Manual Name	Runoff Control Requirements (in addition to state requirements)	BMPs
Environmental Resource Permit Applicant's Handbook Volume II for use within the Geographic Limits of the South Florida Water Management District (May 2016)	N/A (State Regional Manual)	• Wet detention pond • Exfiltration systems • Natural areas and existing waterbodies • Retention basin
South Broward Drainage District Stormwater Management Regulations, Standards, Procedures, and Design Criteria Manual (March 2015)	Volume based on 0.75 to 1.25 inches per day per acre	• Exfiltration Trench
Sarasota County Low Impact Development Guidance Document (May 2015)	Volume Based Treatment System of the runoff from the first 1 inch of rainfall.	• Shallow Bioretention • Pervious Pavement Systems • Stormwater Harvesting • Green Roof Stormwater Treatment Systems • Rainwater Harvesting Detention with Biofiltration
Duval County Low-Impact Development Design Manual (July 2013)	None	• Grassed Conveyance Swales • Shallow Bioretention • Pervious Pavements
Pinellas County Stormwater Manual (February 2017)	For discharges to open drainage basins, maintain existing site condition peak flow based on the 25-year, 24-hour event. For discharges to closed drainage basins, retain the increase in runoff volume based on the 24-hour 100-year event with antecedent moisture condition. existing site condition peak flow based on the 25-year, 24-hour event. The total post development volume leaving the site shall be no more than the total pre-development volume based on the 100-year storm.	• Retention Basin • Exfiltration Trench • Underground Storwate and Retention System • Treatment Swales • Vegetated Natural Buffers • Pervious Pavement Systems • Green Roof/Cistern Systems • Wet Detention Systems • Stormwater Harvesting Systems • Up-Flow Filter Systems • Managed Aquatic Plant Systems • Biofiltration Systems with Biosorption Activated Media • Rain Gardens • Rainwater Harvesting • Rainfall Interceptor Trees

Manual Name	Runoff Control Requirements (in addition to state requirements)	BMPs
Hillsborough County Stormwater Management Technical Manual (October 2015)	The maximum allowable discharge into a County system is limited to the peak discharge based on the five-year storm and the predeveloped condition. Retention or treatment of 0.5 inch of runoff from the entire site.	BMPs not included in Manual.

Table A.2. LID projects in Florida (adapted from Rankin 2015 which references ASLA 2015)

Project Name	Location	Project Description	Design Features	Cost Impact	Performance Measures
Naples Botanical Garden	Naples	Stormwater discharges outfall into River of Grass graded to preserve natural flowpath	Bioretention, Rain Garden, Bioswale	Higher cost than traditional stormwater management but long term benefits exist	River of Grass is at the core of the botanical gardens
Tampa Bay Office Park Waterscape	Tampa	Create prestigious office complex through wetland preservation and restoration	Bioretention, porous pavers, curb cuts	10% or greater savings over traditional; specifically reduced construction and operation & maintenance cost	Initially used as a model stormwater management site by FDEP
Hillsborough Community College – Southshore	Ruskin	Parking lot fitted with bioswale, cistern for toilet flusing & irrigation	Bioretention, Rain garden, bioswale, cistern	Slight increase in project cost	Maximized stormwater treatment
Florida Civil Water Center	Jacksonville	New construction to include green technologies and LID	Bioretention, rain garden, bioswale, green roof	10% or greater savings	Promotion of cultural heritage and nature tourism
Florida Aquarium	Tampa	Parking lot runoff used in treatment train approach	Rain garden, bioswale, pond	Saved on cost by reducing curbing and pipes	Public education
Magdalene Reserve	Tampa	Reduced clearing and grading, hybrid wet and dry stormwater management	Bioretention, bioswale, downspout removal, preservation of native soils and vegetation	Lot by lot grading more expensive due to design, 2 more lots were added which resulted in a net reduction in cost	By preserving native soils and vegetation, infiltration is increased resulting in terminal pond rarely discharging

References:

ASLA. (2015 nd). American Society of Landscape Architects. Accessed 07 August 2018 from Stormwater Case Studies: http://www.asla.org/stormwatercasestudies.aspx

Rankin, Laura Kathren, "Evaluation of Low-Cost Low Impact Development Practices in Southwest Florida for the Control of Urban Runoff " (2015). Graduate Theses and Dissertations.

APPENDIX B: CHECKLISTS

Contents:

Pre-Concept Checklist

Shaded areas are to be completed by the Town of Cutler Bay ONLY.			
Plan Name:	______________________________	**File No:**	____________
Date Received:	______________________________		

Directions: Indicate whether or not the item/information is included with the plan by placing an X in the Yes, No or NA boxes. Please provide a response for each item. Yes = Item included. No = Item not available or not included. NA = Not applicable. Checklist elements that require additional data/testing/surveys that are not yet completed can be can be marked as "No Data" if the tests have not been performed yet.

Yes	No	No Data	NA	Item Description and/or Information *(Maps shall be provided at a scale commensurate with construction drawings, and no less than 1" = 50', except where noted below.)*	Town Staff Notes
				GENERAL INFORMATION	
				1. Applicant information (name, legal address and telephone number)	
				2. Common address, parcel number, and legal description of site	
				3. Date(s) of report preparation and any revision(s)	
				4. Name and contact information of responsible designer	
				5. Vicinity map including:	
				a. North arrow	
				b. Scale	
				c. Adjacent roadways	
				d. Property lines for the site	
				e. Right-of-way lines of streets and/or easements	
				f. Other information as necessary to locate the development site	
				g. Utility access or other easements	
				6. Narrative describing the proposed project.	
				7. USGS Quadrangle map(s), showing the location of the property	
				8. Topography, provided at 2-foot contour intervals with 1-foot accuracy	
				9. Watershed name(s) if known (C-100, C-1 and/or DA-4)	
				EXISTING CONDITION	
				1. General land cover description	
				2. Location of onsite and adjacent streams, regulatory floodplains, regulated/designated stream buffers, wetlands, conservation areas, highly urban soils, and slopes greater than 15%	
				3. Potential pollutant sources	
				4. Areas where wet conditions or flooding is known to have occurred	
				5. Flow paths and drainage basins	
				6. Available geotechnical information, including: • Soil Survey Information • Hydrologic Soil Groups • Subsurface conditions • Depth to Groundwater • On-site Soil Evaluation • Infiltration Test Results • Other necessary geotechnical information	
				7. Other______________________________	
				8. Other______________________________	

				PROPOSED CONDITION	
				1. Land cover types for all areas, both pervious and impervious.	
				2. Impervious surface area (provide total impervious surface area and impervious area within each onsite drainage basin)	
				3. Flow paths and drainage basins	
				4. Selection, location and boundaries of stormwater BMPs and soil restoration areas	
				5. Selection and location of stormwater conveyance system features, whether natural or man-made, that will receive and convey stormwater from proposed site improvements, including storm drains, inlets, catch basins, pipes, channels, swales and areas of overland flow. Each feature shall be identified by type, material, vegetative cover (if any), and dimensions (depth, width, diameter, side slope, etc.).	
				6. Location, boundaries and dimensions of proposed channel modifications, such as a bridge or culvert crossings	
				7. Utility corridors and roadway rights-of-way	
				8. Potential pollutant sources (runoff from parking areas, dumpsters, etc.)	
				9. Other____	
				10. Other____	

Notes:

Stormwater Report Checklist

Shaded areas are to be completed by the Town of Cutler Bay ONLY.		
Plan Name:	____	**File No:** ______________
Date Received:	____	

Directions: Indicate whether or not the item/information is included with the plan by placing an X in the Yes, No or NA boxes. Please provide a response for each item. Yes = Item included. No = Item not available or not included. NA = Not applicable.

Yes	No	NA	**Item Description and/or Information** *(Maps shall be provided at a scale commensurate with construction drawings, and no less than 1" = 50', except where noted below.)*	Town Staff Notes
			GENERAL INFORMATION	
			1. Applicant information (name, legal address and telephone number)	
			2. Common address, parcel number, and legal description of site	
			3. Date(s) of report preparation and any revision(s)	
			4. Name and contact information of responsible designer	
			5. Vicinity map including:	
			a. North arrow	
			b. Scale	
			c. Adjacent roadways	
			d. Property lines for the site	
			e. Right-of-way lines of streets and/or easements	
			f. Other information as necessary to locate the development site	
			g. Utility access or other easements	
			6. Narrative describing the proposed project.	
			7. USGS Quadrangle map(s), showing the location of the property	
			8. Topography, provided at 2-foot contour intervals with 1-foot accuracy	
			9. Watershed name(s) (C-100, C-1 and/or DA-4)	
			10. Professional Engineer stamp and signature	
			EXISTING CONDITION	
			1. General land cover description	
			2. Location of onsite and adjacent streams, regulatory floodplains, regulated/designated stream buffers, wetlands, conservation areas, highly urban soils, and slopes greater than 15%	
			3. Potential pollutant sources	
			4. Areas where wet conditions or flooding is known to have occurred	
			5. Flow paths and drainage basins	
			6. Geotechnical information, including: • Soil Survey Information • Hydrologic Soil Groups • Subsurface conditions • Depth to Groundwater • On-site Soil Evaluation • Infiltration Test Results • Other necessary geotechnical information	
			7. Other____	
			8. Other____	

			PROPOSED CONDITION	
			1. Land cover types for all areas, both pervious and impervious. Note: eroding or bare soil areas (e.g., pervious areas with no vegetation, soil stockpile areas) are not permitted anywhere onsite after construction without appropriate pollution prevention measures to prevent sediment discharges to the onsite stormwater drainage system, BMPs or offsite.	
			2. Impervious surface area (provide total impervious surface area and impervious area within each onsite drainage basin)	
			3. Flow paths and drainage basins	
			4. Pre and post development discharge rate based on the 25-year design storm event. (The runoff discharge rates shall be limited to pre-development conditions based on the 25-year design storm event.)	
			5. Water surface elevation of nearby water systems as well as the depth to seasonally high groundwater	
			6. Selection, location and boundaries of stormwater BMPs and soil restoration areas	
			7. Design data from nearby storm sewer structures	
			8. Selection and location of stormwater conveyance system features, whether natural or man-made, that will receive and convey stormwater from proposed site improvements, including storm drains, inlets, catch basins, pipes, channels, swales and areas of overland flow. Each feature shall be identified by type, material, vegetative cover (if any), and dimensions (depth, width, diameter, side slope, etc.).	
			9. Location, boundaries and dimensions of proposed channel modifications, such as a bridge or culvert crossings	
			10. Utility corridors and roadway rights-of-way	
			11. Roadway and drainage profiles, cross sections, utility plans	
			12. Potential pollutant sources (runoff from parking areas, dumpsters, etc.)	
			13. Other____	
			14. Other____	
			BMPs	
			1. Narrative describing how stormwater is managed on site.	
			2. A map showing all property drainage basins and associated BMPs, showing the proposed land cover within each drainage basin (impervious or pervious) and the expected condition of each land cover (stabilized by paving or permanent vegetation) during and immediately after BMP installation. *(Note that construction sequencing shall be such that BMPs are installed only after permanent stabilization of the BMP's contributing drainage area to reduce construction impacts.)*	
			3. Map(s) and associate narratives that indicate the measures used to protect stormwater quality BMPs after their installation to ensure vegetation survival (if applicable), soil compaction prevention (if applicable), erosion prevention and sediment control within and to the BMP, and structural or environmental damage.	
			4. Construction equipment and other encroachments are restricted from BMP infiltration areas.	
			5. Plan for soil testing, soil restoration, soil amendments, and/or engineered soil media established.	
			6. A table that lists the proposed BMPs that include vegetation and required vegetation type(s) and coverage percentage(s).	
			7. Description and/or drawings indicating the species and planting of proposed vegetation.	
			8. Descriptions and/or drawings indicating the planting practices that will be utilized.	
			9. Narrative or explanatory table *for each vegetated BMP*, providing: a. Expected time of vegetation installation; b. Measures to be employed to protect the vegetation after installation;	

			c. Measures to be employed to ensure the survival of vegetation after its installation and while the property is still under construction, such as watering, fertilization, pest management, etc. Indicate how often such measures will be needed and where/how water will be obtained.	
			10. Infiltration testing of native soils at proposed elevation of infiltration BMP	
			11. Other:	
			12. Other:	
			LID EVALUATION *(Report shall include an evaluated of each listed LID technique for use on the development site. Indicate each technique used with 'yes' and each technique evaluated but not utilized as 'NA')*	
			1. Protect Existing Vegetation	
			2. Enhancing Highly Urban Soils	
			3. Selecting Native Vegetation	
			4. Minimizing Impervious Cover	
			5. Use Preserved Natural Features	
			6. Water Conservation and Reuse	
			7. Meeting Multiple Regulations	
			8. Other____	
			9. Other____	
			10. Other____	

Notes:

Operation & Maintenance Checklist

Shaded areas are to be completed by the Town of Cutler Bay ONLY.

Plan Name: ____ **File No:** ____________

Date Received: ____

Directions: Indicate whether or not the item/information is included with the plan by placing an X in the Yes, No or NA boxes. Please provide a response for each item. Yes = Item included. No = Item not available or not included. NA = Not applicable.

Yes	No	NA	**Item Description and/or Information** *(Maps shall be provided at a scale commensurate with construction drawings, and no less than 1" = 50', except where noted below.)*	Town Staff Notes
			General Information	
			1. Project owner information (name, legal address and telephone number)	
			2. Common address and legal description of site	
			3. Date(s) of report preparation and any revision(s)	
			4. Name and contact information of responsible designer	
			5. Signature and stamp of registered engineer/landscape architect and landscape architect.	
			BMP and Site Plans	
			1. Site plan with labeled drainage area boundaries and associated BMP.	
			2. Site plan with labeled land cover types for all areas (pervious and impervious), and adjacent streams, regulatory floodplains, regulated/designated stream buffers, wetlands, conservation areas, highly urban soils, and slopes greater than 15%	
			3. Site plan with labeled watershed boundaries and watershed name(s) (C-100, C-1 and/or DA-4)	
			4. Other:	
			5. Other:	
			Annual Inspection Requirements	
			1. BMP inspection checklist and instructions for submittal by a Professional Engineer to Public Works each year. Checklist includes inspection and maintenance for the following items, as applicable to onsite BMPs:	
			2. Inspection of the areas where stormwater flows into or out of the BMP for clogging or sediment buildup.	
			3. Inspect trees, shrubs, and other vegetation to ensure they meet landscaping and vegetation specifications. Replace if necessary.	
			4. Inspect the property for erosion, exposed soil, or stockpiles of other potential pollutants and address areas.	
			5. Perform weeding, pruning, and trash removal as needed to maintain appearance.	
			6. Inspect vegetation to evaluate health, replace if necessary.	
			7. Keep inlets clear of debris to prevent clogging, clear if necessary.	
			8. Inspect BMPs for sediment build up, erosion, vegetative health/conditions, etc., Perform appropriate maintenance as necessary.	
			9. Inspect underdrain cleanout to ensure stormwater infiltrates properly. Clean-out underdrain if necessary.	
			10. Other:	
			11. Other:	

Notes: